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Technical Report M-294
October 1981

PAVEMENT MAINTENANCE MANAGEMENT FOR ROADS AND PARKING LOTS

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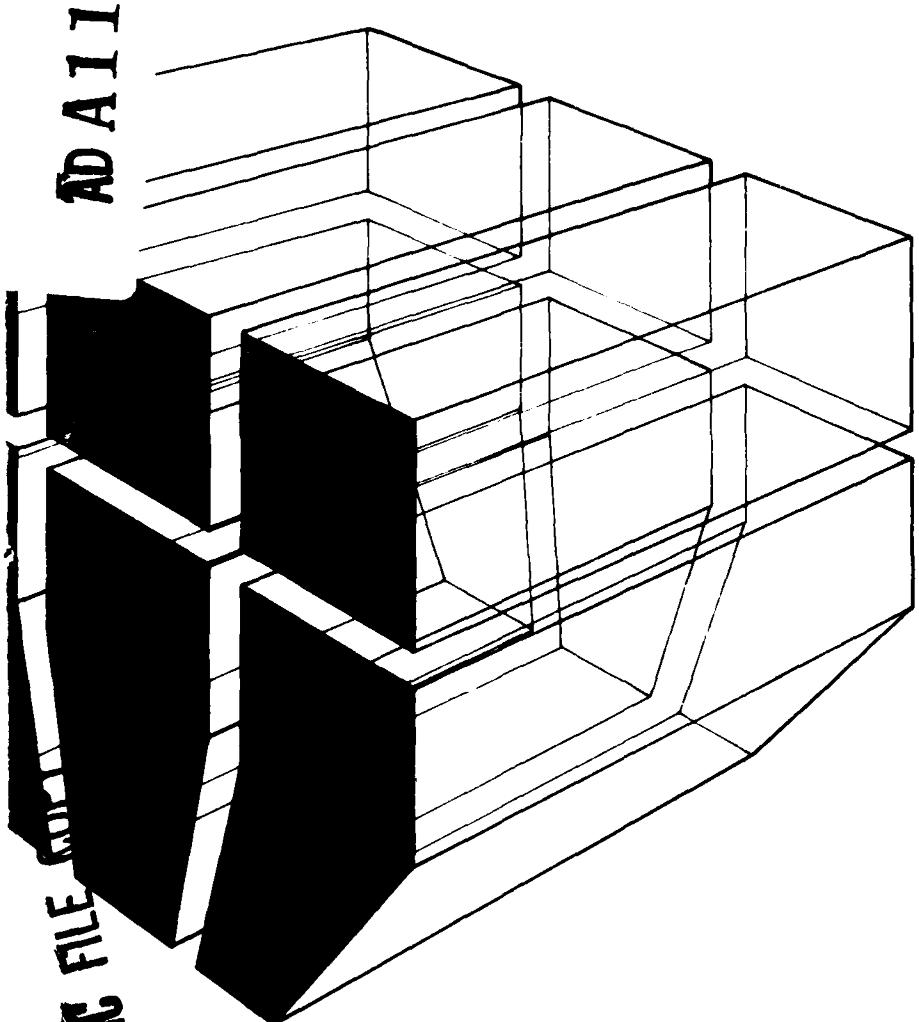

by
M. Y. Shahin
S. D. Kohn

CERL

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Louis J. Circeo
LOUIS J. CIRCEO
Colonel, Corps of Engineers
Commander and Director

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes PAVER, a field-tested, validated pavement maintenance management system for military installations which is designed to optimize the funds allocated for pavement maintenance and rehabilitation (M&R).

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The system includes procedures for dividing the pavement into manageable sections, pavement condition survey and rating, pavement evaluation, rational determination of M&R needs and priorities, performance of life-cycle costing on feasible M&R alternatives, and manual and automated systems for data storage and retrieval. The automated system provides custom-designed reports based on stored and/or processed data.

An important part of PAVER is the pavement condition survey and rating procedure. The procedure is based on the Pavement Condition Index (PCI), which is a numerical indicator from 0 to 100. The PCI measures the pavement's structural integrity and surface operational condition and is computed as a function of distress type, severity, and quantity.

The PAVER system offers the flexibility of implementation at various levels. The highest level of implementation would be the inclusion of all pavements on the installation and use of the automated system. The lowest level would be the use of the PCI as the basis for project approvals and establishment of priorities. A gradual implementation includes starting with a specific group of pavements (such as primary roads) and then including other pavements on a predefined schedule.

FOREWORD

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The work was performed by the Engineering and Materials (EM) Division, U.S. Army Construction Engineering Research Laboratory (CERL). Dr. R. Quattrone is Chief of EM.

COL Louis J. Circeo is Commander and Director of CERL, and Dr. L. R. Shaffer is Technical Director.

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PAVEMENT MAINTENANCE MANAGEMENT
FOR ROADS AND PARKING LOTS

1 INTRODUCTION

Background

Most of the in-service pavements on military installations were built many years ago; few new pavements are being constructed now. Many of the existing pavements have deteriorated to conditions considered costly because they damage vehicles, slow travel, increase energy consumption, and often result in the need for emergency repairs. A great deal of money is spent annually on emergency repair, such as the filling of potholes. Since these repairs are temporary and must be repeated periodically, much more money is spent over the pavement life than is necessary.

Unfortunately, maintenance and rehabilitation (M&R) funds cannot keep pace with the rate of emergency repairs; thus there is a need for a standard, practical decision-making procedure that can be applied to all installations to define what M&R work should be done.

Purpose

The purpose of this report is to describe PAVER, a field-tested and validated pavement maintenance management system designed to optimize the allocation of M&R funds for pavements.

Outline of Report

Chapter 2 discusses network identification: the process of dividing pavement networks into manageable sections to inspect the pavement and determine M&R needs and priorities. Chapter 3 treats pavement condition inspection: the process of examining the pavement to determine existing distresses and their severity, and to compute the pavement condition index (PCI) -- a scoring system that measures the pavement's structural integrity and surface operational condition. Chapter 4 deals with M&R determination: the process of assigning M&R needs and priorities based on inspection data, PCI, and other relevant information such as traffic loading and pavement structural composition. Chapter 5 explains economic analyses of M&R alternatives: the process of using life-cycle cost analysis to rank various M&R alternatives. A manual system (card system) for handling data is described in Chapter 6. An automated system is described briefly in Chapter 7; the advantages of the automated system over the manual system and situations where its use is recommended are also given in Chapter 7.

2 PAVEMENT NETWORK IDENTIFICATION

Introduction

Before PAVER can be used, the installation pavements must be divided into components. This chapter defines the process. The guidelines for division of airfield pavements are given in AFR 93-5.[1]

Definitions

Pavement Network

An installation's pavement network consists of all surfaced areas which provide accessways for ground or air traffic, including roadways, parking areas, hardstands, and airfield pavements.

Branch

A branch is any identifiable part of the pavement network which is a single entity and has a distinct function. For example, individual streets and parking areas are separate branches of a pavement network. Similarly, airfield pavements such as runways, taxiways, and aprons are separate branches.

Section

A section is a division of a branch; it has certain consistent characteristics throughout its area or length. These characteristics are structural composition (thickness and materials), construction history, traffic, and pavement condition.

Sample Unit

A sample unit is any identifiable area of the pavement section; it is the smallest component of the pavement network. Each pavement section is divided into sample units for pavement inspection.

For asphalt- or tar-surfaced pavements (including asphalt overlay of concrete), a sample unit is defined as an area of about 2500 sq ft (± 1000 sq ft). For concrete pavements with joint spacing less than or equal to 30 ft, the sample unit is an area of 20 slabs (± 8 slabs). For slabs with joint spacing more than 30 ft, imaginary joints should be assumed. These imaginary joints should be less than 30 ft apart. This is done for the purpose of defining the sample unit. For example, if slabs have a joint spacing of 50 ft, imaginary joints may be assumed at 25 ft. Thus, each slab would be counted as two slabs for the purpose of pavement inspection. See AFR 93-5 for size of sample units for airfield pavements.

[1] Airfield Pavement Evaluation Program, Air Force Regulation 93-5 (Department of the Air Force [DAF], 1981).

Guidelines for Pavement Identification

Dividing the Pavement Network Into Branches

The first step in using PAVER is to identify the pavement branches. The easiest way to identify these branches is to use the installation's existing name identification system.

For example, Marshall Street in Figure 1 would be identified as a branch. Areas such as parking lots and storage areas that do not have names already assigned can be given descriptive names which associate them with their area.

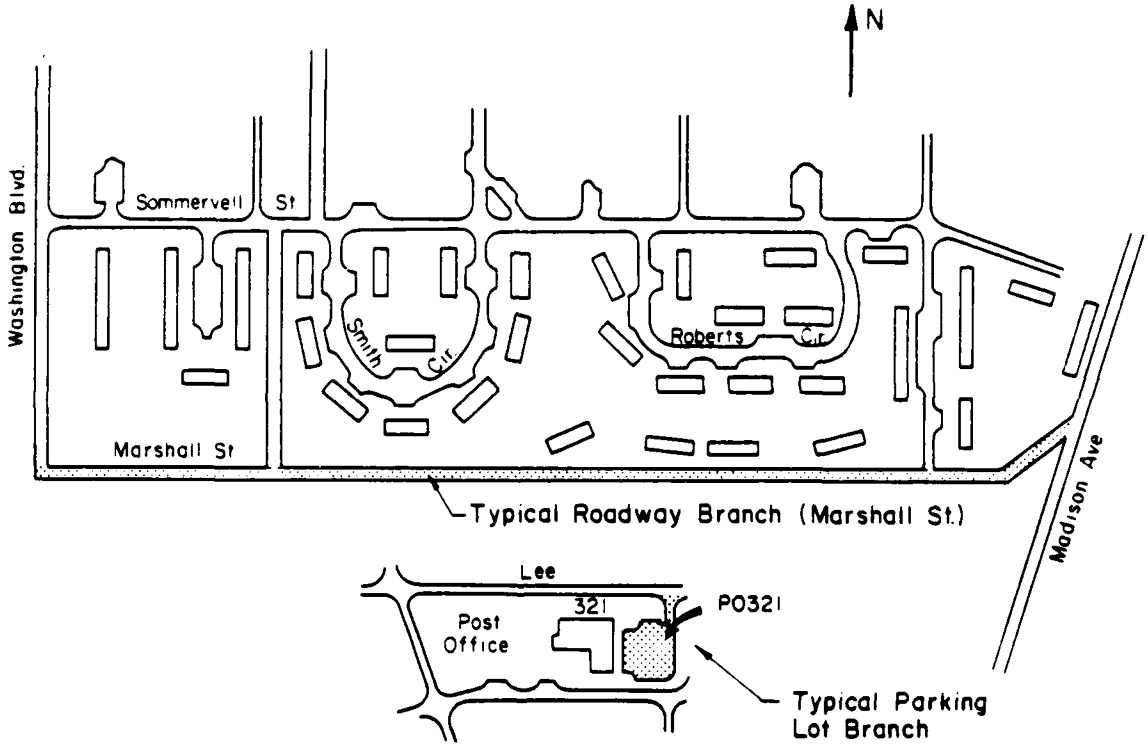


Figure 1. Installation map showing typical pavement branches.

In addition to descriptive names, branches are assigned a unique code to help store and retrieve data from the PAVER files. This code has five characters which are numbers or letters given to the branches using any logical order. The first letter of the code will identify the type of branch as shown in Table 1. For example, the parking lot near Building 321 shown in Figure 1 is given the code P0321. (P stands for parking, and 0321 is the building number.)

Dividing Branches Into Sections

Since branches are large units of the pavement network, they rarely have consistent or uniform characteristics along their entire length. Thus, for

Table 1

Branch Codes

Type of Branch	First Letter in Branch Code
Installation road	I
Parking lot	P
Motor pool	M
Storage/hardstands	S
Runway	R
Taxiway	T
Helicopter pad	H
Apron	A
Other	X

pavement management, each branch must be subdivided into sections with consistent characteristics. As defined previously, a section must have uniform structural composition, traffic, and the same construction history.

After each section is initially inspected, pavement condition within the section can be used to subdivide it into other sections if a considerable variation in condition is encountered. For example, a section containing part of a two-lane road that has one lane in a significantly different condition than the other lane should be subdivided into two sections. Unique situations such as those that occur at roadway intersections should also be placed in separate sections. However, it must be remembered that the major section's structure usually carries through an intersection. The structure should be checked if there is doubt as to which pavement would continue through the intersection. Some guidelines for dividing pavement network branches into sections are:

1. Pavement structure. Structure is one of the most important criteria for dividing a branch into sections. Structural information is not always available for all branches of a pavement network. To collect structure information, available construction records can be searched and patching repairs can be observed. In addition, pavement coring programs can be developed to determine the structural composition of remaining pavement sections or to verify existing information.

2. Traffic. The volume and load intensity of traffic should be consistent within each individual section.

3. Construction history. All portions of a section should have been constructed at the same time. Pavement constructed in intervals should be divided into separate sections corresponding to the dates of construction. Areas that have received major M&R work should also be considered as separate sections.

4. Pavement rank. Pavement rank can also be used to divide a branch into sections. If a branch changes along its length from primary to secondary, or secondary to tertiary, a section division should be made. If a branch becomes a divided roadway along its length, a separate section should be defined for each direction of traffic.

5. Drainage facilities and shoulders. It is recommended that shoulder type and drainage facilities be consistent throughout a section.

By using the criteria in paragraphs 1 through 5 above, the pavement branches can be divided into sections. Sections are numbered beginning with 1 at the north or west end of the branch. The numbers then increase in a southerly or easterly direction. Each section should be identified on the installation map.

To identify a section on the installation map, place an arrow at the starting point and ending point of each section (Figure 2). Sample units should be numbered in ascending order from the beginning of each section.

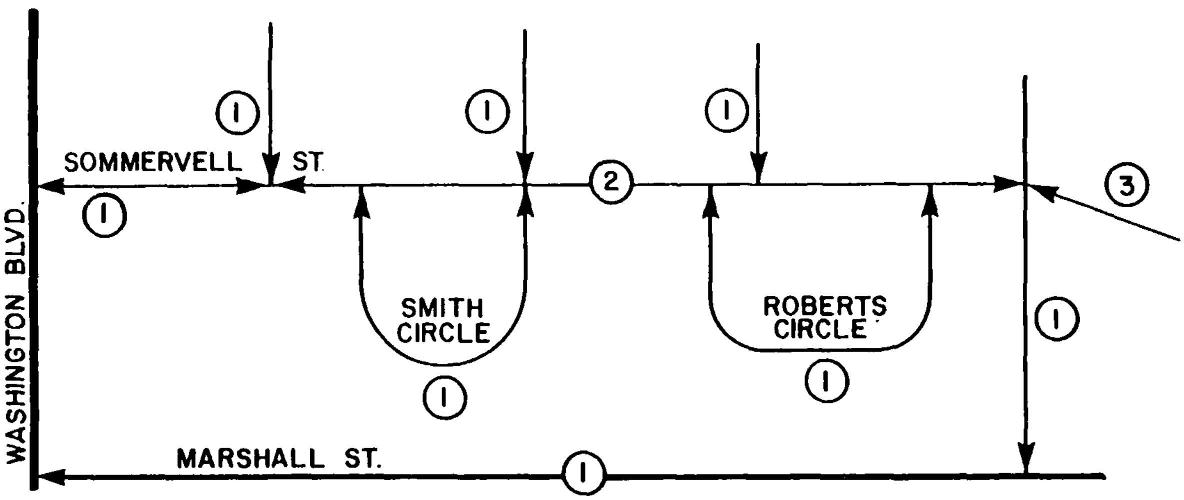


Figure 2. Sections identified on an installation.

The information given above that applied to roadways may also be applied to branch types such as parking areas, storage areas, etc. These branch types are usually considered one section but may be subdivided. For example, a parking lot could be divided into more than one section; if the parking lot's drive areas were well defined, each drive area would be identified as a separate section.

Small parking lots (usually allowing parking of fewer than 10 vehicles each) may be considered as one section if they are located relatively near each other and have consistent characteristics. For example, Figure 3 shows a grouping of small parking lots around Smith Circle. These lots may be considered as a branch with one section. However, if the lots are relatively large and/or do not have consistent characteristics, such as those shown bordering Somerville in Figure 3, they may be defined as one branch, but each lot should be considered an individual section.

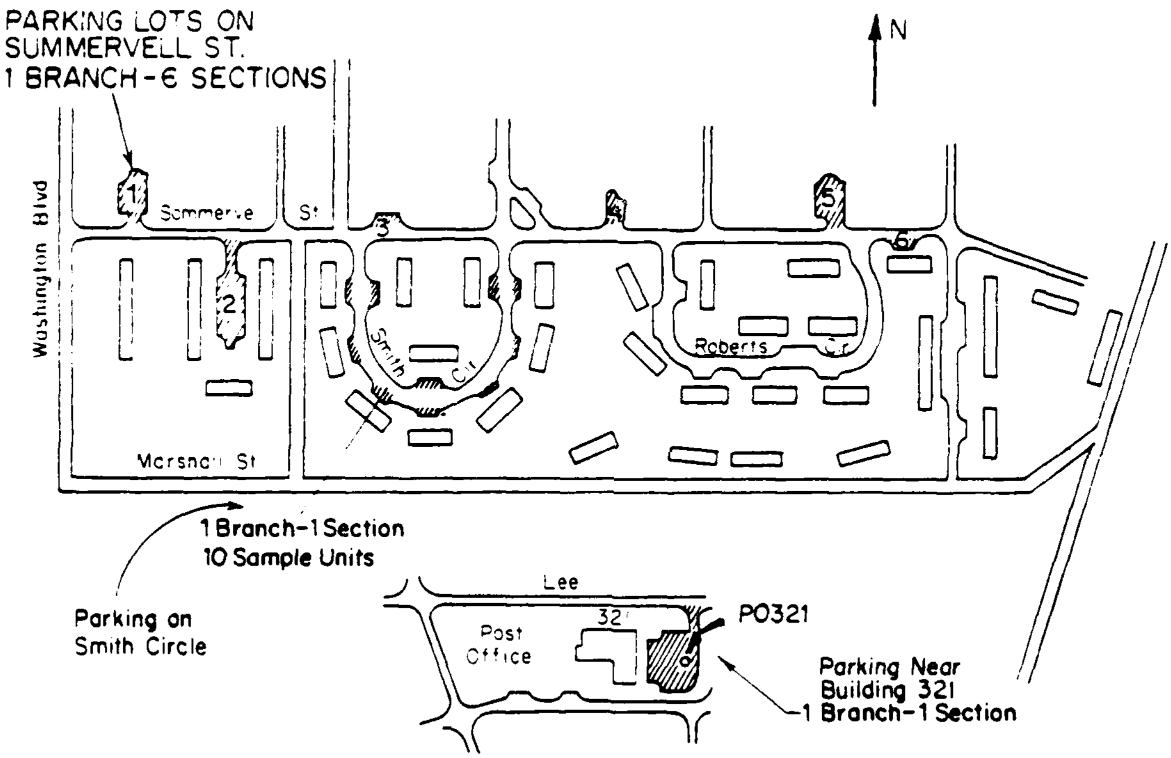


Figure 3. Installation map showing various methods of identifying parking area branches.

An example of dividing a parking area into sections is shown in Figure 4. The area is very large and defined as one branch with five sections. The basic division of sections is based on traffic patterns and use. Field observations of these types of branches will help decide how to divide such an area into sections.

Dividing a Section Into Sample Units

A sample unit is the smallest component of the pavement network and is used for inspection purposes to determine existing pavement distress and condition.

The sizes of the sample units are described in detail on p 10. For asphalt pavements, a sample unit may vary in size from approximately 1500 sq ft to 3500 sq ft, with a recommended average of 2500 sq ft. For concrete

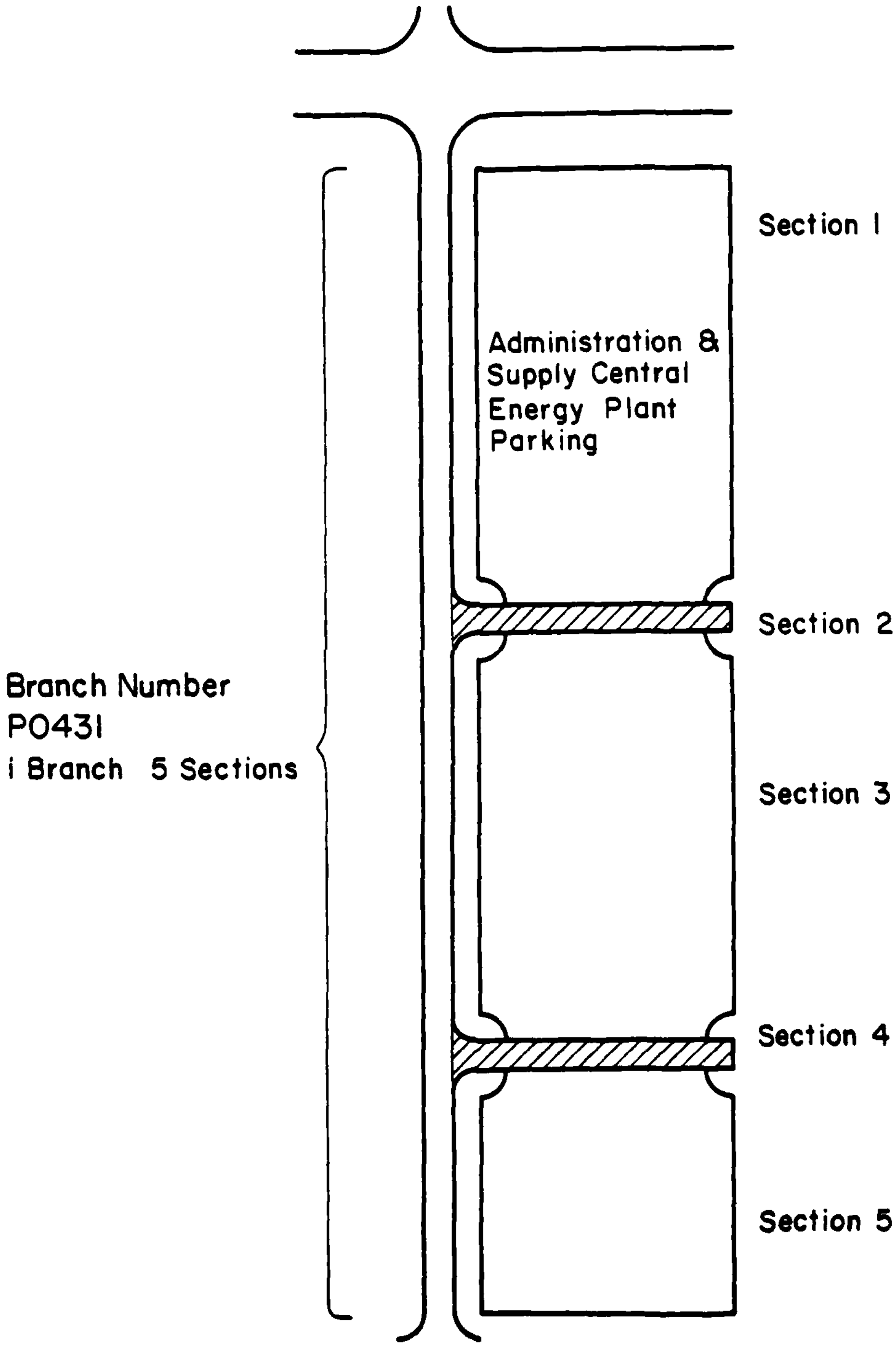


Figure 4. Large parking area divided into several sections.

pavement, a sample unit may vary in size from approximately 12 to 28 slabs, with a recommended average of 20 slabs. A significant criterion in selecting a typical sample unit size for a section is convenience. For example, an asphalt pavement section that is 22 ft wide by 4720 ft long can be divided into sample units that are 22 ft wide by 100 ft long, or 2200 sq ft. The last sample units of the section may have to be of different lengths because of the length of the section. In the above example, the section is divided into 46 units that are each 100 ft long and one unit that is 120 ft long. Thus, the last sample unit has an area of 22 x 120 or 2640 sq ft. The above example is shown in Figure 5.

A schematic diagram of each section (such as that shown in Figure 5) should be made showing the size and location of its sample units. These sketches are required for future inspections to relocate the sample units.

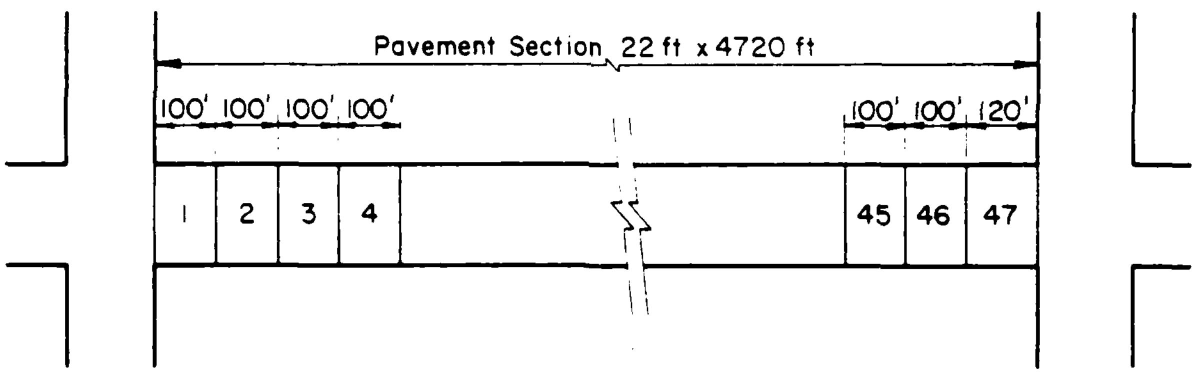


Figure 5. Example of an asphalt section divided into sample units.

3 PAVEMENT CONDITION SURVEY AND RATING PROCEDURES

Introduction

An important component of PAVER is the pavement condition survey and rating procedures. Data obtained from these procedures are the primary basis for determining M&R requirements and priorities. This chapter explains how to conduct a condition survey inspection and how to determine the pavement condition index (PCI). It is essential to have a thorough working knowledge of the PCI and condition survey inspection techniques.

Pavement Condition Rating

Pavement condition is related to several factors, including structural integrity, structural capacity, roughness, skid resistance/hydroplaning potential, and rate of deterioration. Direct measurement of all of these factors requires expensive equipment and highly trained personnel. However, these factors can be assessed by observing and measuring distress in the pavement.

PCI

The pavement condition rating is based on the PCI, which is a numerical indicator based on a scale of 0 to 100. The PCI measures the pavement's structural integrity and surface operational condition. Its scale and associated ratings are shown in Figure 6. A similar pavement condition rating procedure for airfields has been implemented worldwide by the Air Force (AFR 93-5).

Determination of PCI

The PCI is determined by measuring pavement distress. The method has been field-tested and has proven to be a useful device for determining M&R needs and priorities.

Pavement Inspection

General

Before a pavement network is inspected, it must be divided into branches, sections, and sample units as described in Chapter 2. Once this division is complete, survey data can be obtained and the PCI of each section determined.

Inspection Procedures for Jointed Concrete Pavement Sections

There are two methods to inspect a pavement. Both methods require that the pavement section be divided into sample units. The first method -- entire section inspection -- requires that all sample units of an entire pavement section be inspected. The second method -- inspection by sampling -- requires that only a portion of the sample units in a section be inspected. For both methods, the sample units must be assigned sample unit numbers.

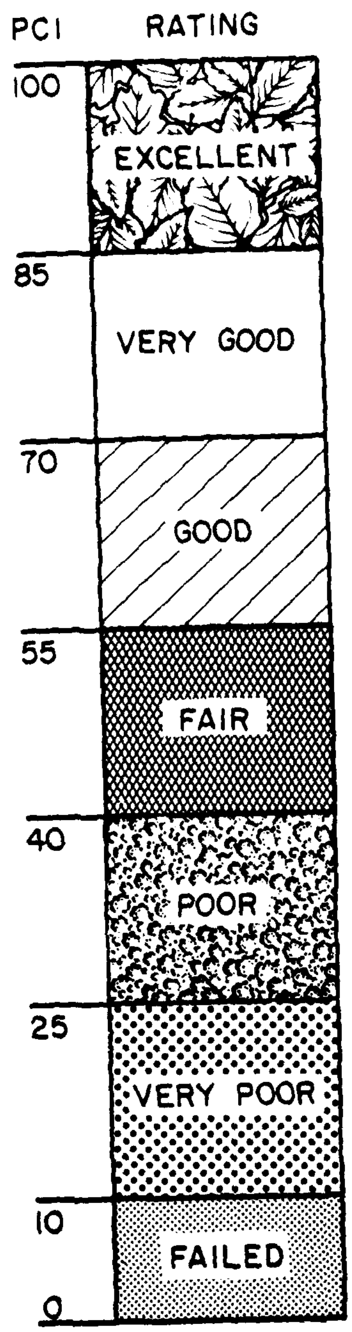


Figure 6. PCI scale and condition rating.

For entire section inspections, the inspector walks over each slab in each sample unit, or from the shoulder if traffic control is not provided, and records the distress(es) observed on a Sample Unit Inspection Sheet (see Figure 7). One sheet is used for each sample unit. The inspector sketches the sample unit using preprinted dots as joint intersections (imaginary joints should be labeled). The appropriate number code for each distress found in the slab is entered in the square representing the slab. The letter L (low), M (medium), or H (high) is included along with the distress number code to indicate the severity level of the distress. Distresses and severity level definitions are listed in Appendix A. Since the PCI was based on these definitions, it is imperative that the inspector follow the appendix closely when performing an inspection.

The equipment needed to perform a survey is a hand odometer for measuring slab size, a 10-ft straightedge and a ruler for measuring faulting and lane/shoulder drop off, and the PCI distress guide (Appendix A).

The Sample Unit Inspection Sheet has space for a summary of each distress and severity level(s) of distress contained in the sample unit. These data are used to compute the PCI for the sample unit as outlined on p 28. Figure 8 is an example data sheet showing the summary of distresses for a jointed concrete sample unit.

Inspection Procedures for Asphalt, Tar-Surfaced, and/or Asphalt Over Concrete Pavement

As with jointed concrete pavements, the pavement section must first be divided into sample units. During either the entire section inspection or inspection by sampling, the inspector walks over each sample unit, measures each distress type and severity, and records these data on the asphalt- or tar-surfaced Sample Unit Inspection Sheet (Figure 9).

The equipment needed is a hand odometer used to measure distress lengths and areas, a 10-ft straightedge, a ruler to measure the depth of ruts or depressions, and some type of paint or marking to identify the end of the unit.

One data sheet is used for each sample unit. Each column on the data sheet is used to represent a distress type, and the amount and severity of each distress identified is listed in the column. For example, in Figure 10, distress No. 6 (depression) is recorded as 6x4L, which indicates that the depression is a 6-ft x 4-ft area and of low severity. Distress No. 10 (longitudinal and transverse cracking) is measured in linear ft; thus, 10L indicates 10 ft of light cracking, 5M indicates 5 ft of medium cracking, etc. The total distress data are used to compute the PCI for the sample unit as outlined on p 28. An example summary of the distress densities and severities for an asphalt- or tar-surfaced sample unit is shown in Figure 10.

Remarks

For both jointed concrete and asphalt- or tar-surfaced pavement, it is important that each sample unit be identified well enough for it to be relocated for additional inspection, comparison with future inspections, maintenance requirements, and random sampling purposes. One way to do this is to

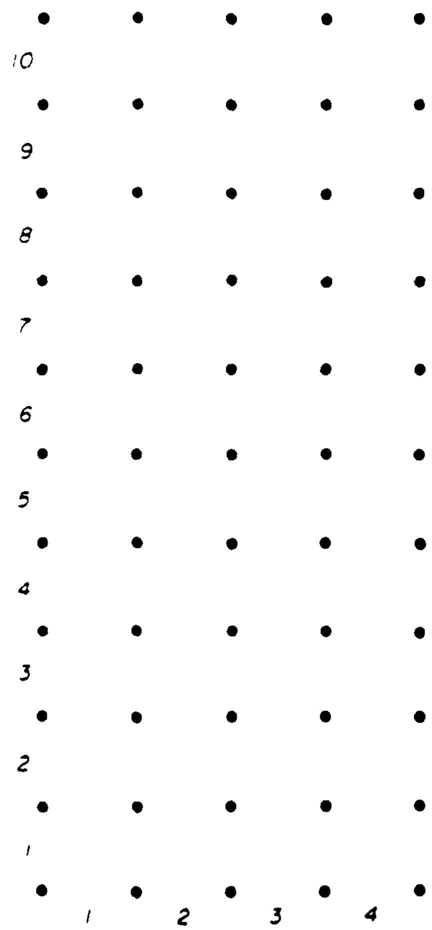
FORM A

CONCRETE PAVEMENT INSPECTION SHEET

BRANCH ______________________ SECTION ______________

DATE __________________________ SAMPLE UNIT __________________

SURVEYED BY __________________ SLAB SIZE __________________



Distress Types

21. Blow-Up Buckling/Shattering
22. Corner Break
23. Divided Slab
24. Durability ("D") Cracking
25. Faulting
26. Joint Seal Damage
27. Lane/Shldr Drop Off
28. Linear Cracking
29. Patching, Large & Util Cuts
30. Patching, Small
31. Polished Aggregate
32. Popouts
33. Pumping
34. Punchout
35. Railroad Crossing
36. Scaling/Map Cracking/Crazing
37. Shrinkage Cracks
38. Spalling, Corner
39. Spalling, Joint

DIST TYPE	SEV.	NO SLABS	% SLABS	DEDUCT VALUE
26*				
DEDUCT TOTAL				
CORRECTED DEDUCT VALUE (CDV)				

PCI = 100 - CDV = ____________

RATING = ____________

* All Distresses Are Counted On A Slab-By-Slab Basis Except Distress 26, Which Is Rated For the Entire Sample Unit.

Figure 7. Jointed concrete sample unit inspection sheet.

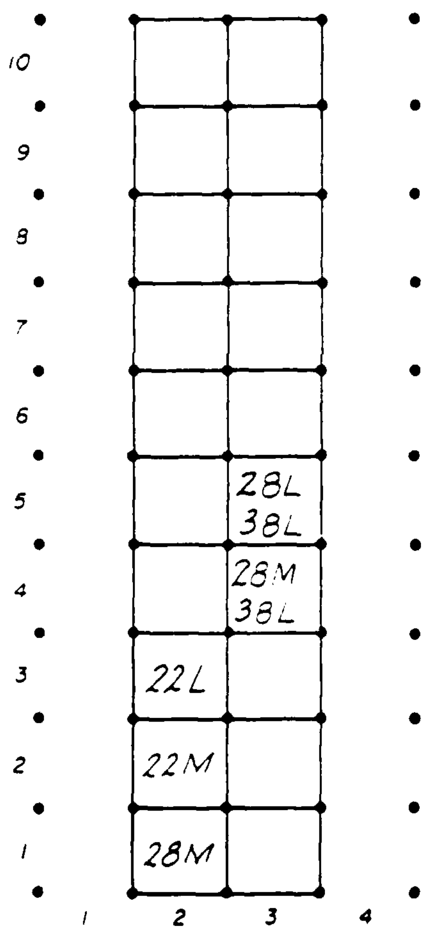
FORM A

CONCRETE PAVEMENT INSPECTION SHEET

BRANCH MARSHALL AVE. SECTION 1

DATE 10/3/79 SAMPLE UNIT 7

SURVEYED BY SK SLAB SIZE 15 x 20



Distress Types

21 Blow-Up Buckling/Shattering
22. Corner Break
23. Divided Slab
24 Durability ("D") Cracking
25 Faulting
26. Joint Seal Damage
27. Lane/Shldr Drop Off
28. Linear Cracking
29 Patching, Large & Util Cuts
30 Patching, Small
31 Polished Aggregate
32 Popouts
33 Pumping
34 Punchout
35. Railroad Crossing
36 Scaling, Map Cracking/Crazing
37 Shrinkage Cracks
38. Spalling, Corner
39 Spalling, Joint

DIST. TYPE	SEV.	NO.** SLABS	% SLABS	DEDUCT VALUE
26*	M			4
22	L	1	5	4
22	M	1	5	8
28	L	1	5	3
28	M	2	10	9
38	L	2	10	1
DEDUCT TOTAL q = 2				29
CORRECTED DEDUCT VALUE (CDV)				24

PCI = 100 - CDV = 76

RATING = VERY GOOD

* All Distresses Are Counted On A Slab-By-Slab Basis Except Distress 26, Which is Rated For the Entire Sample Unit

** Total Number of Slabs Containing Each Distress of Same Severity

Figure 8. Completed jointed concrete sample unit inspection sheet.

FORM B

ASPHALT PAVEMENT INSPECTION SHEET

BRANCH ____________________ SECTION _______________

DATE ____________________ SAMPLE UNIT _______________

SURVEYED BY ________________ AREA OF SAMPLE ____________

Distress Types

		SKETCH:
1. Alligator Cracking	*10. Long & Trans Cracking	
2. Bleeding	11. Patching & Util Cut Patching	
3. Block Cracking	12. Polished Aggregate	
*4. Bumps and Sags	*13. Potholes	
5. Corrugation	14. Railroad Crossing	
6. Depression	15. Rutting	
*7. Edge Cracking	16. Shoving	
*8. Jt Reflection Cracking	17. Slippage Cracking	
*9. Lane/Shldr Drop Off	18. Swell	
	19. Weathering and Raveling	

	EXISTING DISTRESS TYPES					
TOTAL SEVERITY L						
TOTAL SEVERITY M						
TOTAL SEVERITY H						

PCI CALCULATION

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE
DEDUCT TOTAL			
CORRECTED DEDUCT VALUE (CDV)			

PCI = 100 - CDV =

RATING =

* All Distresses Are Measured In Square Feet Except Distresses 4,7,8,9 and 10 Which Are Measured In Linear Ft; Distress 13 Is Measured in Number of Potholes.

Figure 9. Blank asphalt-surfaced pavement sample unit inspection sheet.

FORM B

ASPHALT PAVEMENT INSPECTION SHEET

BRANCH [illegible] SECTION 1
DATE [illegible] SAMPLE UNIT 1
SURVEYED BY SK AREA OF SAMPLE 2500

Distress Types		SKETCH:
1. Alligator Cracking	*10. Long & Trans Cracking	N
2. Bleeding	11. Patching & Util Cut Patching	100'
3. Block Cracking	12. Polished Aggregate	25'
*4. Bumps and Sags	*13. Potholes	DIRECTION SURVEYED
5. Corrugation	14. Railroad Crossing	
6. Depression	15. Rutting	
*7. Edge Cracking	16. Shoving	
*8. Jt Reflection Cracking	17. Slippage Cracking	
*9. Lane/Shldr Drop Off	18. Swell	
	19. Weathering and Raveling	

	EXISTING DISTRESS TYPES					
	10	1	15	6		
	10L	x6L	2x25L	2x4L		
	5L	2x8M				
	5L					
	5M					
	5L					
	5M					
TOTAL SEVERITY L	40	6	50	24		
TOTAL SEVERITY M	10	16				
TOTAL SEVERITY H						

PCI CALCULATION

DISTRESS TYPE	DENSITY	SEVERITY	DEDUCT VALUE
1	0.24	L	4
1	0.64	M	[illegible]
6	0.96	L	4
10	.60	L	4
10	0.4	M	3
15	2.0	L	3
DEDUCT TOTAL	q = 2		45
CORRECTED DEDUCT VALUE (CDV)			33

PCI = 100 - CDV = 67

RATING = GOOD

* All Distresses Are Measured In Square Feet Except Distresses 4,7,8,9 and 10 Which Are Measured in Linear Ft; Distress 13 is Measured in Number of Potholes

Figure 10. Asphalt-surfaced pavement sample unit inspection sheet showing distress data and PCI calculations.

keep a file of previous inspection data, including a sketch of the section which shows the location of each sample unit (see Figure 5 as an example).

It is imperative that the distress definitions listed in Appendix A be used when performing pavement inspections. If these definitions are not followed, an accurate PCI cannot be determined.

Inspection by Sampling

General

Inspection of every sample unit in a pavement section may require considerable effort, especially if the section is large. Because of the time and effort involved, frequent surveys of an entire section subjected to heavy traffic volume may be beyond available manpower, funds, and time. Therefore, a sampling plan was developed to allow adequate determination of the PCI and M&R requirements by inspecting only a portion of the sample units in a pavement section.

The number and location of sample units to be inspected depends on the purpose of inspection. If the purpose is to determine the overall condition of the pavement in the network (e.g., initial inspection to identify projects, budget needs, etc.), then a survey of one or two sample units per section may suffice. The units should be selected to be representative of the overall condition of the section.

However, if the purpose is to analyze various M&R alternatives for a given pavement section (e.g., project design, etc.), then more sampling should be performed. The following sections present the sampling procedure for this purpose.

Determining the Number of Samples

The first step in performing inspection by sampling is to determine the minimum number of sample units (n) that must be surveyed. This is done by using Figure 11.

The curves shown in Figure 11 are used to select the minimum number of sample units that must be inspected. This will provide a reasonable estimate of the true mean PCI of the section. The estimate is within $\pm$ 5 points of the true mean PCI about 95 percent of the time. The curves were constructed using the following equation:

$$n = \frac{N\sigma^2}{\frac{e^2}{4}(N-1) + \sigma^2} \qquad \text{[Eq 1]}$$

where N = total number of sample units in the pavement section; e = allowable error in the estimate of the section PCI (e is set equal to 5 when constructing curves in Figure 11); and σ = standard deviation of the PCI between sample units in the section.

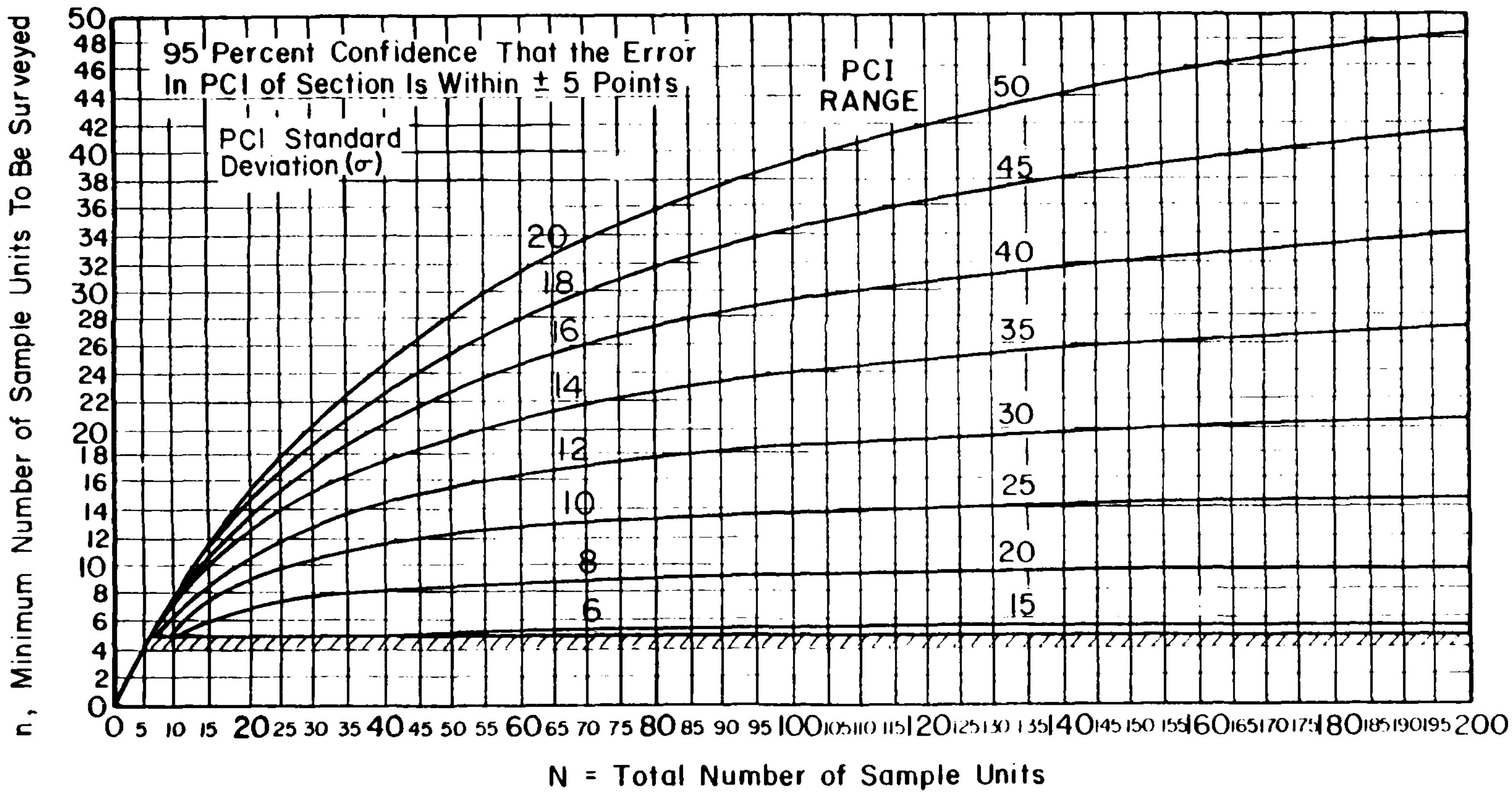


Figure 11. Determination of minimum number of sample units to be surveyed.

$$\sigma = \sqrt{\frac{\sum_{i=1}^{R} (PCI_i - \overline{PCI})^2}{R-1}} \quad \text{[Eq 2]}$$

where R = number of sample units in the pavement section surveyed upon which σ is determined, PCI_i = PCI of sample unit i, and $\overline{PCI}$ = mean PCI of section.

$$\overline{PCI} = \frac{\sum_{i=1}^{R} PCI_i}{R} \quad \text{[Eq 3]}$$

The curves in Figure 11 can be used based on the PCI standard deviation among sample units or PCI range (i.e., lowest sample unit PCI subtracted from the highest sample unit PCI). When performing the initial inspection, the PCI standard deviation for a pavement section is assumed to be 10 for asphalt concrete (AC)-surfaced pavements (or PCI range of 25) and 14 for Portland cement concrete (PCC)-surfaced pavements (or PCI range of 35). For subsequent inspections, the actual PCI standard deviation or range (determined from the previous inspection) is used to determine the minimum number of sample units to be surveyed. As illustrated in Figure 11, when the total number of samples within the section is less than 5, every sample unit should be surveyed. If N is greater than 5, at least five sample units should be surveyed.

Selection of Samples

Determining specific sample units to inspect is as important as determining the minimum number of samples (n) to be surveyed. The recommended method for selecting the samples is to choose samples that are equally spaced; however, the first sample should be selected at random. This technique, known as systematic sampling, is illustrated in Figure 12 and is briefly described below.

1. The "sampling interval" (i) is determined by i = N/n, where N = total number of available sample units, n = minimum number of sample units to be surveyed, and i is rounded off to the smaller whole number (e.g., 3.6 is rounded to 3).

2. The random start (s) is selected at random between 1 and the sampling interval (i). For example, if i=3, the random start would be a number from 1 to 3.

3. The sample units to be surveyed are identified as s, s + i, s + 2i, s + 3i, etc. If the selected start is 3, then the samples to be surveyed are 6, 9, 12, etc. (See Figure 12.) This technique is simple to apply and also gives the information necessary to establish a PCI profile along the pavement section.

Selection of Additional Sample Units

One of the major objections to sampling is the problem of not including "very poor" or "excellent" sample units which may exist in a section. Another

Total Number of Sample Units In Section (N) = 47

Minimum Number of Units To Be Surveyed (n) = 13

Interval (i) = $\frac{N}{n} = \frac{47}{13} = 3.6 \qquad = 3$

Random Start (S) = 3

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47

Figure 12. Example selection of sample units to be surveyed.

problem is the selection of a random sample which contains nontypical distresses such as railroad crossings, potholes, etc.

To overcome these problems, the inspector should label unusual sample units as additional sample units. An additional unit implies that the sample was not selected at random and/or contains distress(es) which are not representative of the section.

The calculation of the PCI when additional sample units are included is slightly altered and is described on p 30.

Calculating the PCI From Inspection Results

General

The Inspection by Sampling section described two ways of inspecting a pavement section; i.e., inspecting every unit in the section or inspecting by sampling. Data collected during either method of inspection are used to calculate the PCI. This section explains how to calculate the PCI for a particular sample unit, and how to calculate the PCI for the entire pavement section. An important item in the calculation of the PCI is the "deduct value." A deduct value is a number from 0 to 100, with 0 indicating the distress has no impact on pavement condition, and 100 indicating an extremely serious distress which causes the pavement to fail.

Calculating Sample Unit PCI

Calculating the PCI for a sample unit is a simple procedure which involves five steps (see Figure 13):

Step 1. Each sample unit is inspected and distress data recorded on Form A for concrete or Form B for bituminous pavements as described on p 17 (see Figures 8 and 10).

Step 2. The deduct values are determined from the deduct value curves for each distress type and severity (see Appendix B).

Step 3. A total deduct value (TDV) is computed by summing all individual deduct values.

Step 4. Once the TDV is computed, the corrected deduct value (CDV) can be determined from the correction curves. When determining the CDV, if any individual deduct value is higher than the CDV, the CDV is set equal to the highest individual deduct value. For example, assume that two distresses were found in an asphalt pavement, one with a deduct value of 50, and the other with a deduct value of 10. Using Figure B20 of Appendix B, the CDV for $q=2$ (q = number of individual deduct values greater than 5) is 44. Since 44 is lower than 50, the CDV is set equal to 50.

Step 5. The PCI is computed using the relation PCI = 100 - CDV.

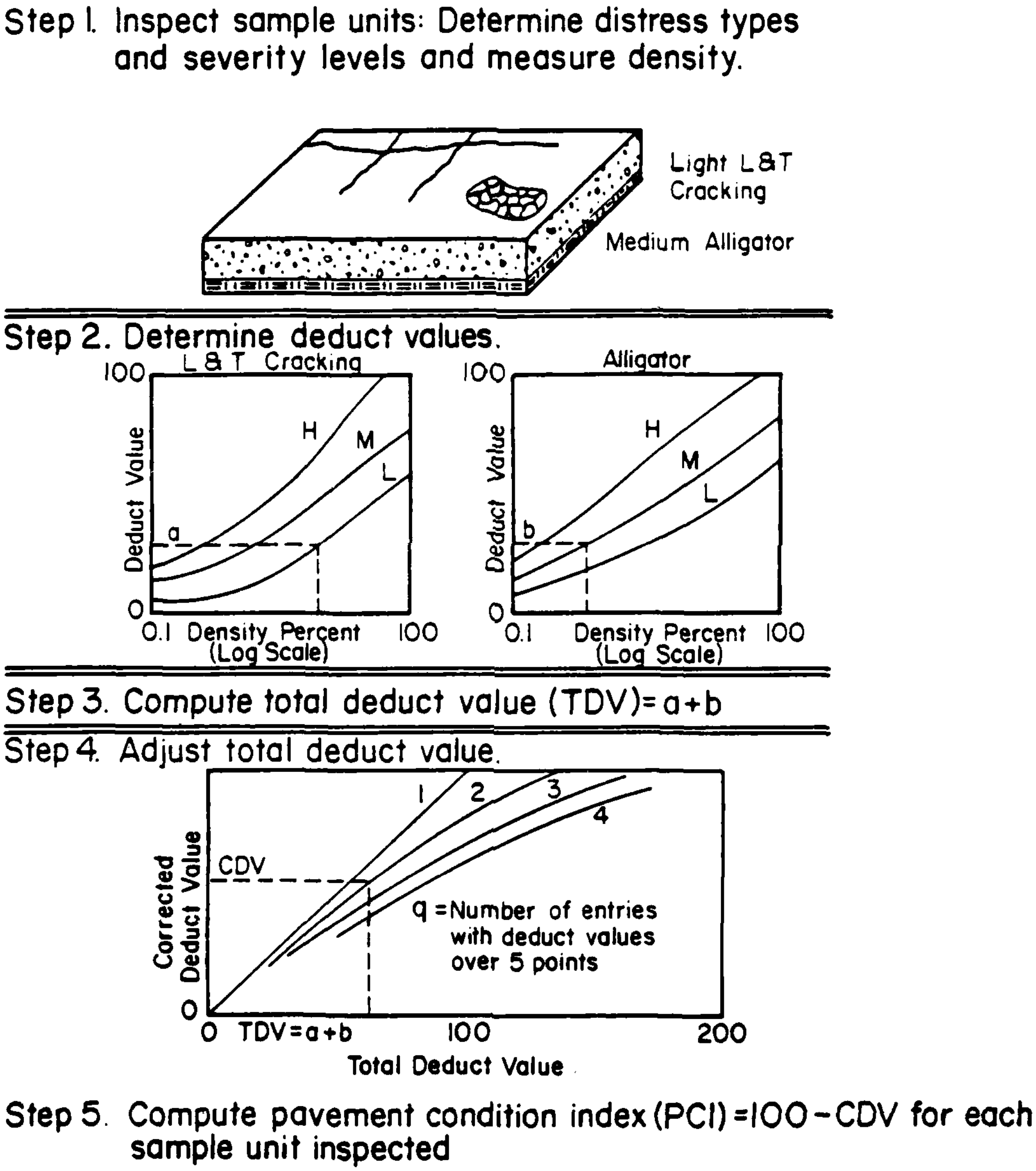


Figure 13. Steps for calculating PCI for a sample unit.

Calculating the PCI for a Pavement Section

If all sample units in a section are surveyed, the PCI of the section is computed by averaging the PCIs of all its sample units. Inspection by sampling, however, requires a different approach. If all surveyed sample units are selected randomly, the PCI of the pavement section is determined by averaging the PCI of its sample units. If any additional sample units are inspected, a weighted average must be used. The weighted average is computed by using the following equation:

$$PCI_s = \frac{(N-A)\ \overline{PCI_1} + A\ PCI_2}{N} \qquad \text{[Eq 4]}$$

where PCI_s = PCI of pavement section, $\overline{PCI_1}$ = average PCI of random samples, PCI_2 = average PCI of additional samples, N = total number of samples in the section, and A = number of additional samples inspected.

Example Calculation of the PCI for a Sample Unit

The field data sheets described on p 17 are always used when calculating the PCI of a sample unit.

Asphalt Pavement Sample Unit (Figure 10). The difference between calculating a PCI for an asphalt sample unit and calculating a PCI for a concrete sample unit is in the way the distress density is determined.

1. Density for distresses measured by the square foot is calculated as follows:

$$\text{Density} = \frac{\text{distress amount in square feet}}{\text{sample unit area in square feet}} \times 100$$

2. Density for distresses measured by the linear foot (bumps, edge cracking, joint reflection cracking, lane/shoulder drop off, and longitudinal and transverse cracking) is calculated as follows (see Appendix A for distress definitions):

$$\text{Density} = \frac{\text{distress amount in linear feet}}{\text{sample unit area in square feet}} \times 100$$

3. Density for distress measured by number (potholes) is calculated as follows:

$$\text{Density} = \frac{\text{number of potholes}}{\text{sample unit area in square feet}} \times 100$$

After the distress density for each distress type/severity combination is calculated, the deduct values are determined from the distress deduct value curves in Figures B1 through B19 of Appendix B. The corrected deduct value is determined from Figure B20 and is calculated as shown in Figure 10.

Jointed Concrete Sample Unit (Figure 8). After inspection, calculate the density of distress as follows:

$$\text{Density} = \frac{\text{number of slabs containing a particular type distress}}{\text{number of slabs in sample unit}} \times 100$$

For example, two slabs in the pavement sample unit shown in Figure 8 contained linear cracking (distress 28) at medium severity, so the density is calculated as $\frac{2}{20} \times 100$, or 10 percent. The deduct values are then determined for each distress combination from the distress deduct value curves given in Figures B21 through B39. The CDV is determined from Figure B40, and the PCI is calculated as shown in Figure 8.

Determination of Distress Quantities for a Pavement Section

When a pavement has been inspected by sampling, it is necessary to extrapolate the quantities and densities of distress over the entire pavement section to determine total quantities for the section.

If all sample units surveyed were selected at random, the extrapolated quantity of a given distress of a given severity level would be determined as illustrated in the following example for medium-severity alligator cracking.

Section Information

Surface type: Asphalt concrete
Area: 24,500 sq ft

Total number of sample units in the section: 10

Five sample units were surveyed at random, and the amount of medium-severity alligator cracking was determined as follows:

Sample Unit ID Number	Sample Unit Area, Sq Ft	Medium-Severity Alligator Cracking, Sq Ft
02	2500	100
04	2500	200
06	2500	150
08	2500	50
10	2000	100
Total Random	12,000	600

The average density for medium-severity alligator cracking is, therefore, $\frac{600}{12,000} = .05$. The extrapolated quantity is determined by multiplying the density by the section area, i.e., $.05 \times 24,500 = 1225$ sq ft.

If additional sample units were included in the survey, the extrapolation process would be slightly different. In the example given above, assume

that sample unit number 01 was surveyed as additional and that the amount of medium-severity alligator cracking was measured as follows:

Additional Sample Unit ID	Sample Unit Area, Sq Ft	Medium-Severity Alligator Cracking, Sq Ft
01	2500	1000
Total Additional	2500	1000

Since 2500 sq ft were surveyed as additional, the section's randomly surveyed area was, therefore, 24,500 - 2,500 = 22,000 sq ft. The extrapolated distress quantity is obtained by multiplying the distress density by the section's randomly surveyed area and then adding the amount of additional distress. In this example:

$$\text{Extrapolated Distress Quantity} = .05 \times 22{,}000 + 1000$$
$$= 2100 \text{ sq ft}$$

4 MAINTENANCE AND REPAIR (M&R) GUIDELINES

Introduction

M&R needs and priorities are highly related to the PCI, since the PCI is determined by distress information which is a key factor in establishing pavement M&R requirements. This chapter describes how to do a pavement evaluation, how to determine feasible M&R alternatives, and how to establish M&R priorities. These guidelines should be based on the PCI, with consideration given to other important factors including pavement load-carrying capacity. A specific M&R alternative can often be selected for a pavement section that is in very good or excellent condition without a life-cycle cost analysis. In cases where a life-cycle cost analysis is necessary to select among feasible alternatives, the life-cycle cost analysis method described in Chapter 5 should be used.

Pavement Evaluation Procedure

Evaluation is performed on a section-by-section basis since each section represents a unit of the pavement network that is uniform in structural composition and subjected to consistent traffic loadings. It is necessary to make a comprehensive evaluation of pavement condition before rational determination of feasible M&R alternatives can be made. A step-by-step description of how to complete the pavement section condition evaluation summary sheet (Figure 14) is given below.

Overall Condition

The PCI of a pavement section describes the section's overall condition. The PCI, and thus the section condition rating (e.g., good or very good), is based on many field tests and represents the collective judgment of experienced pavement engineers. In turn, the overall condition of the section correlates highly with the needed level of M&R. In Figure 14, the rating corresponding to the PCI should be circled on the form.

Variations of the PCI Within Section

PCI variation within a section can occur on a localized random basis, and/or a systematic basis. Figure 15, which was developed from field data, gives guidelines that can be used to determine whether variation exists. When a PCI value of a sample unit in the section is less than the sample unit critical PCI value, a localized random variation exists. For example, if the mean PCI of a section is 59, any sample unit with a PCI of less than 42 should be identified as a localized bad area. If this condition exists, "Yes" under item 2a is circled on the form. This variation should be considered when determining M&R needs. Systematic variation occurs whenever a large, concentrated area of a section has a significantly different condition. For example, if traffic is channeled into a certain portion of a large parking lot, that portion may show much more distress or be in a poorer condition than the rest of the area. Whenever a significant amount of systematic variability exists within a section, the section should be subdivided into two or more sections.

Section Evaluation Summary

1. Overall Condition Rating - PCI __________

Rating -	Failed,	Very Poor,	Poor,	Fair,	Good,	Very Good,	Excellent
PCI	0-10	11-25	26-40	41-55	56-70	71-85	86-100

2. Variation of Condition Within Section -- PCI

   a. Localized Random Variation — Yes, No
   b. Systematic Variation: — Yes, No

3. Rate of Deterioration of Condition -- PCI

   a. Long-term period (since construction or last overall repair) — Low, Normal, High
   b. Short-term period (1 year) — Low, Normal, High

4. Distress Evaluation

   a. Cause

   Load Associated Distress ____percent deduct value
   Climate/Durability Associated ____percent deduct value
   Other (____) Associated Distress ____percent deduct value

   b. Moisture (Drainage) Effect on Distress — Minor, Moderate, Major

5. Deficiency of Load-Carrying Capacity — No, Yes

6. Surface Roughness — Minor, Moderate, Major

7. Skid Resistance/Hydroplaning Potential — Minor, Moderate, Major

8. Previous Maintenance — Low, Normal, High

9. Comments: ____

Figure 14. Pavement section evaluation summary.

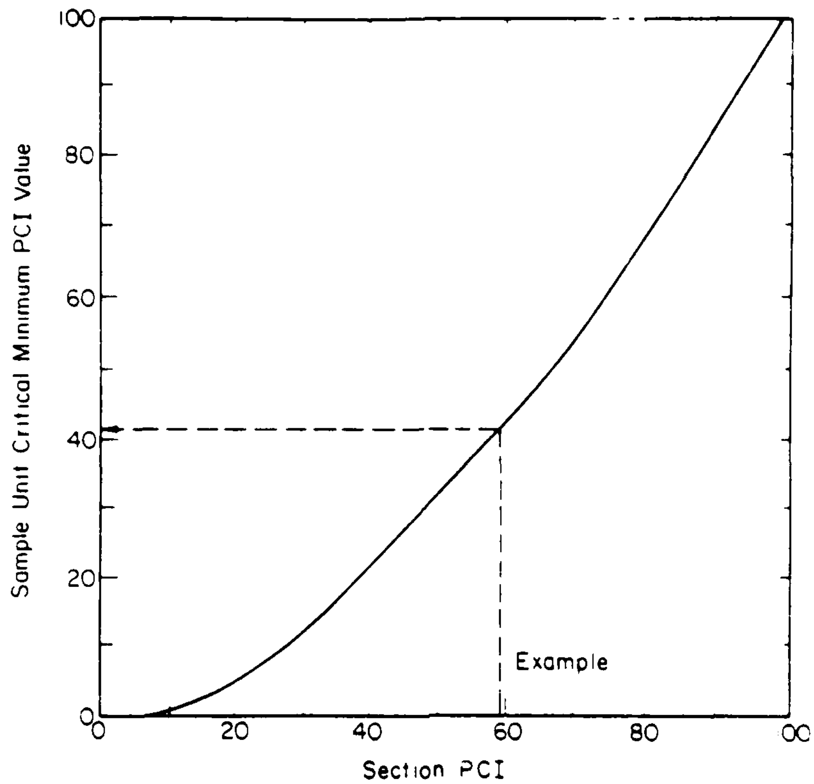


Figure 15. Procedure to determine critical minimum sample unit PCI based on mean PCI of section.

Rate of Deterioration of Condition -- PCI

Both the long- and short-term rate of deterioration of each pavement section should be checked. The long-term rate is measured from the time of construction or time of last overall M&R (such as an overlay). The rate is determined as low, normal, or high using Figures 16 through 19. The figures are for the following four pavement types, respectively: asphalt concrete (AC) pavements, AC overlay over AC pavements, Portland cement concrete (PCC) pavements, and AC overlay over PCC pavements. Development of the curves delineating the low, normal, and high rate of deterioration was based on field data from Fort Eustis. For example, an AC pavement that is 20 years old with a PCI of 50 is considered to have a high long-term rate of deterioration with respect to other AC pavements. Short-term deterioration (i.e., a drop in PCI during the last year) should also be determined since a high short-term deterioration rate can indicate the imminent failure of a pavement section (Figure 20). In general, whenever the PCI of a section decreases by 7 or more PCI points a year, the deterioration rate should be considered high. If the loss in PCI points is 4 to 6, the short-term deterioration rate should be considered normal. It should be emphasized that short-term deterioration rate cannot be accumulated to arrive at long-term rate evaluation.

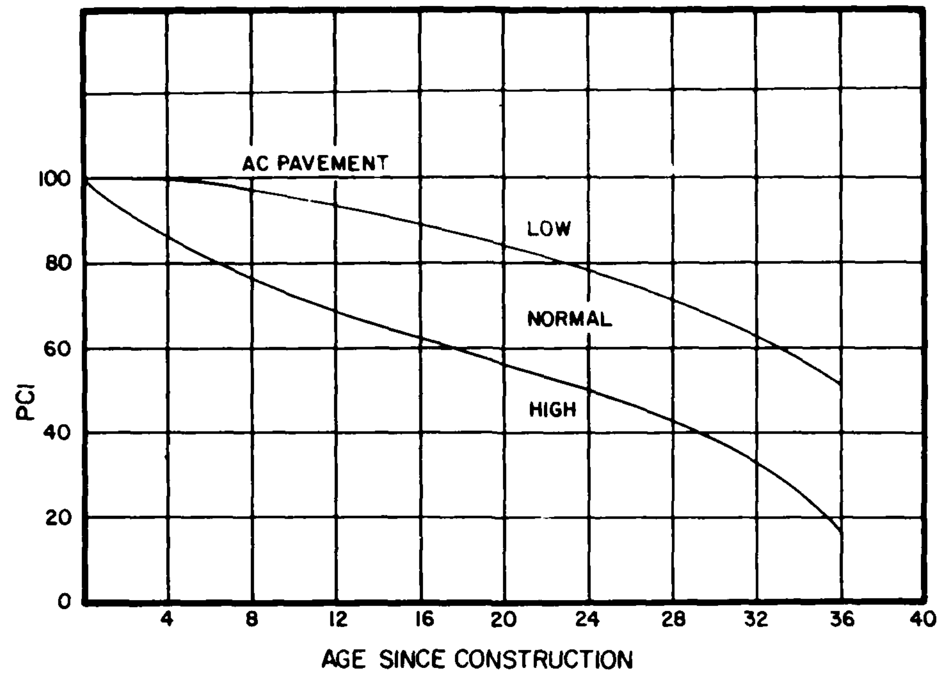


Figure 16. Determination of long-term rate for asphalt concrete (AC) pavements.

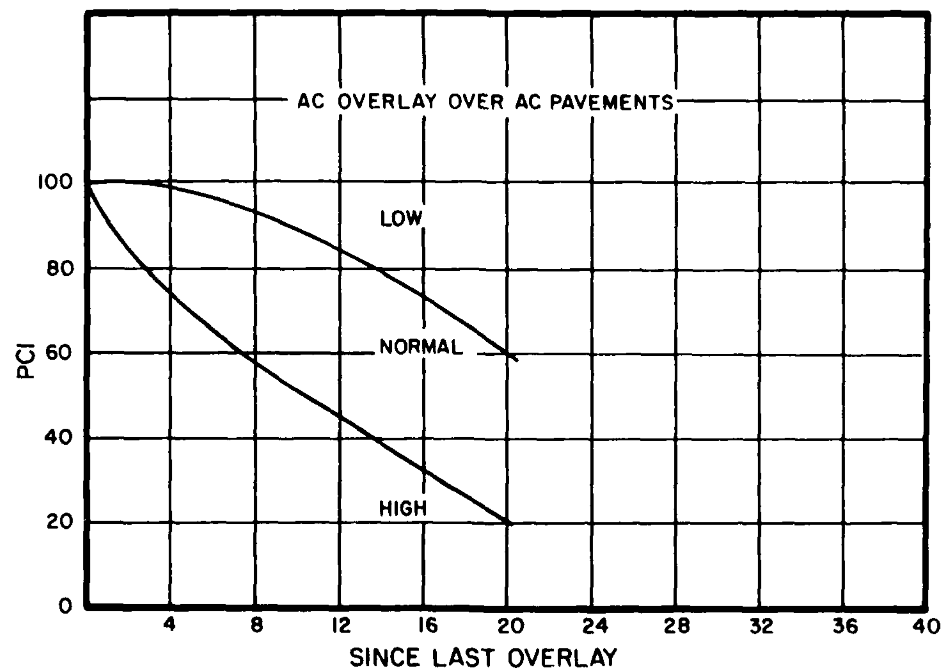


Figure 17. Determination of long-term rate of deterioration for asphalt concrete (AC) overlay over AC pavements.

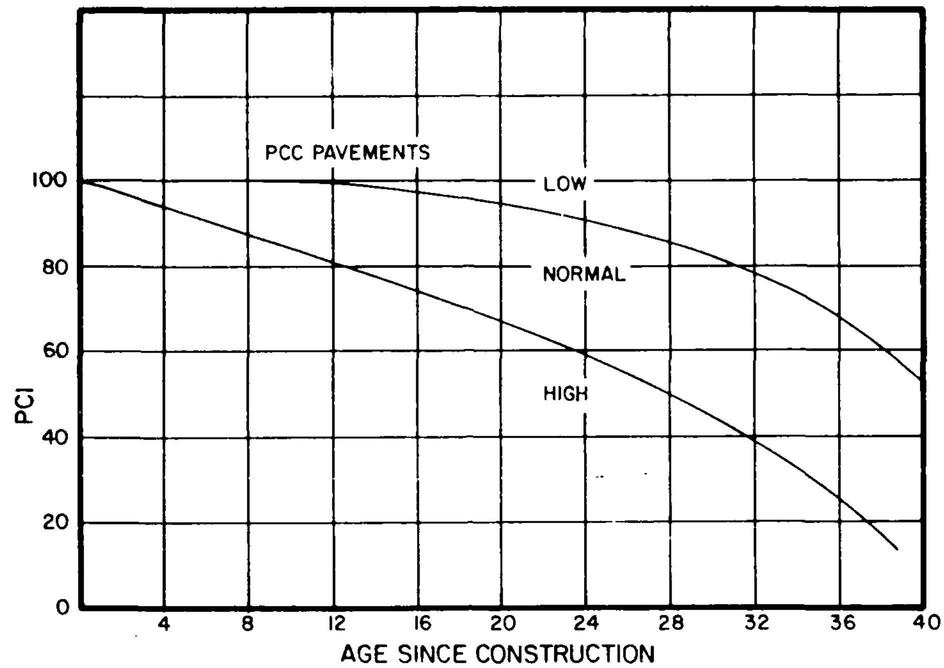


Figure 18. Determination of long-term rate of deterioration for Portland cement concrete (PCC) pavements.

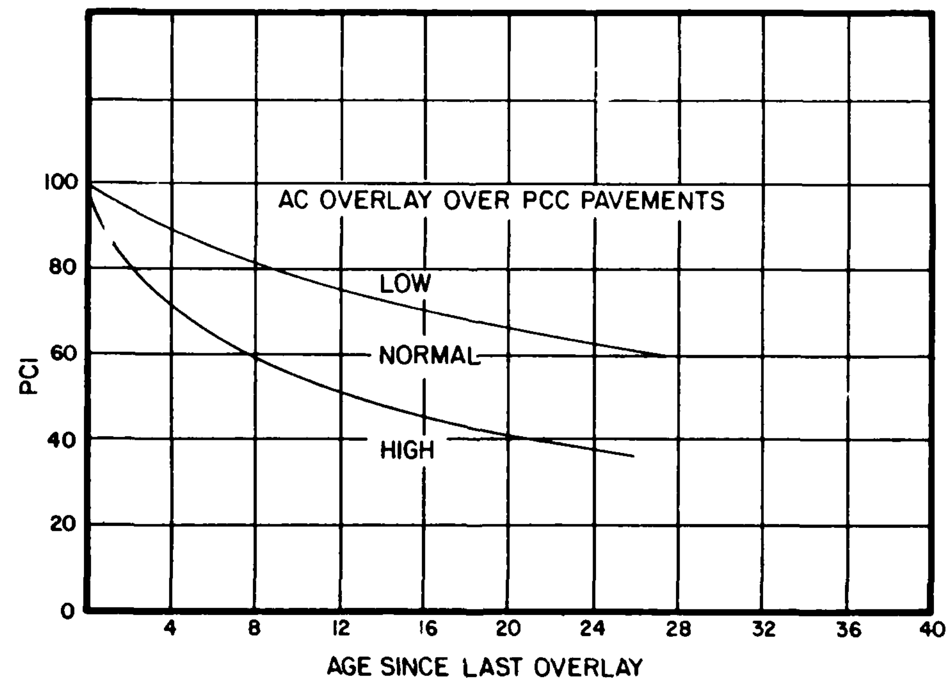


Figure 19. Determination of long-term rate of deterioration for asphalt concrete (AC) overlay over Portland cement concrete (PCC) pavements.

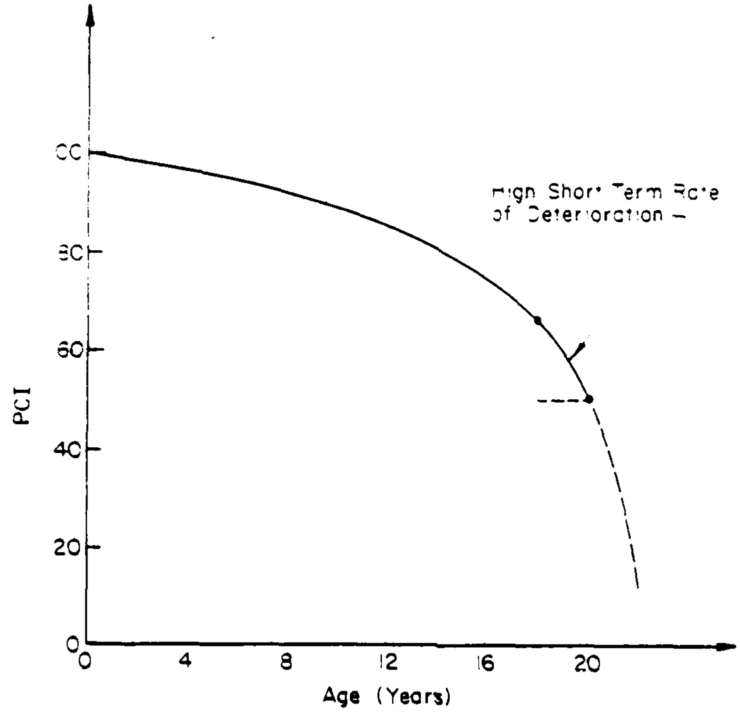


Figure 20. PCI vs. age illustrating high short-term rate of deterioration.

Distress Evaluation

Examination of the specific distress types, severities, and quantities present in a pavement section can help identify the cause of pavement deterioration, its condition, and eventually its M&R needs. Tables 2 and 3 list general classification of distress types for asphalt- and concrete-surfaced pavement according to their cause and effect on pavement conditions. Conditions at each pavement section will dictate which distresses will be placed in each group. For evaluation purposes (Figure 14), distresses have been classified into three groups based on cause: load-associated, climate/durability-associated, and those caused by other factors. In addition, the effect of drainage on distress occurrence should always be investigated. The following steps should be followed to determine the primary cause or causes of pavement condition deterioration for a given pavement section.

The total deduct values (TDVs) attributable to load, climate/durability, and other associated distresses are determined separately. For example, the following distresses and TDV values were measured on an asphalt section of pavement.

Table 2

General Classification of Asphalt Distress Types by Possible Causes

POSSIBLE CAUSES

Load	Climate/ Durability	Moisture/ Drainage	Other Factors
Alligator Cracking	Bleeding	Alligator Cracking	Corrugation
Corrugation	Block Cracking	Depression	Bleeding
Depression	Joint Reflection Cracking	Potholes	Bumps and Sags
	Longitudinal and Transverse Cracking		
Edge Cracking	Patching of Climate/Durability-Swell Caused Distress	Swell	Lane/Shoulder Dropoff
Patching of Road-Caused Distress	Potholes		
Polished Aggregate	Swell		
Potholes	Weathering and Raveling		
Rutting			
Slippage Cracking			

Table 3

General Classification of Concrete Distress Types by Possible Causes

POSSIBLE CAUSES

Load	Climate/ Durability	Moisture/ Drainage	Other Factors
Corner Break	Blow-up	Corner Break	Faulting
Divided Slab	"D" Cracking	Divided Slab	Lane/Shoulder Dropoff
Linear Cracking	Joint Seal Damage	Patching of Moisture-Caused Distress	Railroad Crossing
Patching of Load-Associated Distress	Linear Cracking	Pumping	
Polished Aggregate	Patching of Climate/Durability-Associated Distress		
Punchout	Popouts		
Spalling (joint)	Pumping		
	Scaling		
	Shrinkage Cracks		
	Spalling (joint)		
	Spalling (corner)		

Distress Type	Distress Density Over Section	Severity Level	Deduct Value	Probable Cause
Alligator cracking	10	M	47	Load
Transverse cracking	3	M	17	Climate/ durability
Rutting	5	L	21	Load
Total			85	

The TDV attributable to load is 68; the TDV attributable to climate/durability is 17.

The percentage of deducts attributable to load, climate/durability, and other factors can be computed as described below; the following is based on the previous example.

$$\begin{aligned} \text{Load} &= 68/85 \times 100 = 80 \text{ percent} \\ \text{Climate/durability} &= 17/85 \times 100 = 20 \text{ percent} \\ \text{Total} &= 100 \text{ percent} \end{aligned}$$

The percent deduct values attributable to each cause are the basis for determining the primary cause(s) of pavement deterioration. In the examples given above, distresses caused primarily by load have resulted in 80 percent of the total deducts, whereas all other causes have produced only 20 percent. Thus, traffic load is by far the major cause of deterioration for this pavement section. These percentages should be indicated on the form.

The drainage situation of each pavement section should also be investigated. If moisture is causing accelerated pavement deterioration, it must be determined how it is happening and why (groundwater table, infiltration of surface water, ponding water on the pavement, etc.). If moisture is contributing significantly to the rate of pavement condition deterioration, ways must be found to prevent or minimize this problem. For example, if pumping occurs in concrete joints or cracks, drainage conditions should be examined, and foundation support evaluated. Any drainage and foundation defects should be corrected and the joints or cracks filled or sealed. The appropriate effect should be circled on the form.

Deficiency of Load-Carrying Capacity

Before it can be determined whether an existing pavement section is strong enough to support a particular traffic condition, it is necessary to determine the pavement's load-carrying capacity. Methods for determining

load-carrying capacity are given in AFM 88-7, TM 5-822-5, and TM 5-822-6 for roads and AFM 88-24, TM 5-827-2, and TM 5-827-3 for airfield pavements.[2]

For example, assume an asphalt pavement section has the following structural composition:

Layer	Thickness	California Bearing Ratio (CBR)
Subgrade	--	10
Base	10 in.	40
Surface	4 in.	--

Further assume that this pavement section is a Class A road (see Table 4) subjected to the following traffic load:

Traffic Type	Vehicles/Day	Percent of Total Traffic
Passenger cars	1400	85
Two-axle trucks	200	12
Trucks with three or more axles	50	3

According to the information above and Table 4, the design index for this pavement section is 5. Based on the information in Figure 21, the pavement thickness required over a CBR of 10 is 12.5 in.; over a CBR of 40, the required thickness is 4.0 in. Therefore, this pavement section is structurally strong enough for the load it is carrying, and load-carrying capacity deficiency is circled "No" on the form.

Surface Roughness

Surface roughness is an important operational condition. Although a rough pavement will usually have a low PCI, the reverse is not necessarily true. For example, a pavement section may have a high percentage of medium-severity alligator cracking (a serious structural distress) and, thus, a low PCI. However, if this is the only distress present, the pavement surface may not be rough.

[2] Flexible Pavements for Roads, Streets, Walks, and Open Storage Areas, Chapter 1, TM 5-822-5 (Department of the Army [DA], 1977) and AFM 88-7 (DAF, April 1969); Rigid Pavements for Roads, Streets, Walks, and Open Storage Areas, TM 5-822-6 (DA, 1977); Flexible Airfield Pavement Evaluation, Chapter 2, TM 5-827-2 (DA, 1968) and AFM 88-24 (DAF, October 1968); Rigid Airfield Pavement Evaluation, TM 5-827-3 (DA, 1959).

Table 4

Design Index for Flexible Pavements for Roads and Streets, Traffic Categories I Through IV (From Flexible Pavements for Roads, Streets, Walks, and Open Storage Areas, TM 5-822-5 [DA, June 1971].)

Class Road or Street	Design Index			
	Category I	Category II	Category III	Category IV
A	3	4	5	6
B	3	4	5	6
C	3	4	4	6
D	2	3	4	5
E	1	2	3	4
F	1	1	2	3

Category I. Traffic essentially free of trucks (99 percent group 1, plus 1 percent group 2)

Category II. Traffic including only small trucks (90 percent group 1, plus 10 percent group 2)

Category III. Traffic including small trucks and a few heavy trucks (85 percent group 1, plus 14 percent group 2, plus 1 percent group 3)

Category IV. Traffic including heavy trucks (75 percent group 1, plus 15 percent group 2, plus 10 percent group 3)

Group 1. Passenger cars and panel and pickup trucks
Group 2. Two-axle trucks
Group 3. Three-, four-, and five-axle trucks

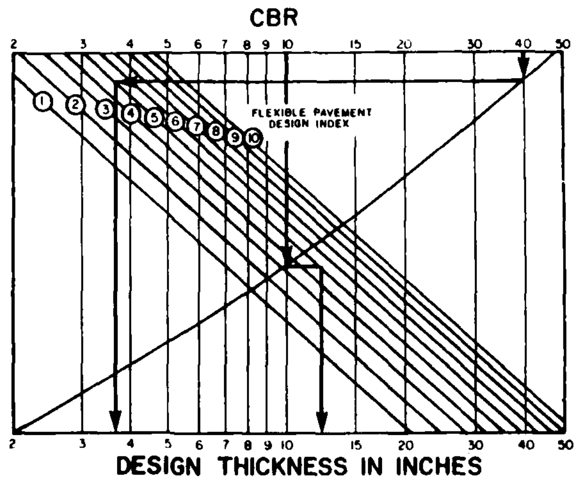


Figure 21. Thickness design requirements for flexible pavements. (From TM 5-822-5, June 1971, and AFM 88-24, Chapter 3).

Minor, moderate, or major surface roughness can be determined by riding over the pavement section at its speed limit and observing its relative riding quality. Enter the evaluation on the form.

Skid Resistance/Hydroplaning Potential

Skid resistance and hydroplaning potential are only of concern for high-speed-traveled roads and airfields. Pavement sections where skid is not of concern should be listed as such on the pavement evaluation sheet. Otherwise, skid resistance must be directly measured with special equipment. If direct measurement is not possible, skid resistance/hydroplaning potential may be evaluated by reviewing distress data. Distress that can cause skid resistance/hydroplaning potential are bleeding, polished aggregates, rutting, and depression (for asphalt pavements) and polished aggregate (for concrete pavements). Enter the evaluation on the form.

Previous Maintenance

A pavement section can be kept in operating condition almost indefinitely if extensive maintenance is performed. However, there are many drawbacks to this maintenance strategy, including overall cost, section downtime, increase in roughness caused by excessive patching, limitations of manpower and equipment, and pavement mission requirements. Therefore, the amount and types of maintenance previously applied to a pavement section must be determined before a new strategy is selected. For example, a pavement with a large patched or replaced portion may have had many distress problems which are likely to continue in the future, and which should be considered in the new strategy.

The evaluation of previous maintenance can be based on the incidence of permanent patching (asphalt pavements), large areas of patching (more than 5 sq ft), and/or slab replacement (concrete pavement). Patching and/or slab replacement ranging between 1.5 to 3.5 percent (based on surface area for asphalt and number of slabs for concrete) is considered normal; more than 3.5 percent is considered high, and less than 1.5 percent is considered low. Some pavement sections may have received an excessive amount of maintenance other than patching. If the engineer feels that a section should be evaluated as having high previous maintenance, then this evaluation should take precedence over evaluation criteria based on only patching and slab replacement. Enter the evaluation on the form.

Comments

Any specific requirements or items that might have an impact on the selection of feasible alternatives should be noted on the form.

Determination of Feasible M&R Alternatives

Assumption

In the process of selecting feasible alternatives, one of the primary assumptions is that the strategy will be implemented within 3 years.

Procedure

The process of selecting feasible M&R alternatives is summarized in Figure 22 and is described below.

Determine M&R Strategy. The purpose of this step is to identify the pavement sections that need comprehensive analysis. The data required for the identification are the PCI, distress, pavement rank, pavement usage, traffic, and management policy.

Based on the factors in the preceding paragraph, a limiting PCI value may be established for each type of pavement; e.g., 75 for primary roads with traffic volume exceeding 10,000 vehicles per day, and 70 for primary roads with traffic volume less than or equal to 10,000 vehicles per day. If a pavement section has a PCI above the limiting value, continuation of existing maintenance policy is recommended unless review of the distress data shows that the majority of distress is caused by inadequate pavement strength and/or the rate of pavement deterioration is thought to be high. If any of these factors exists, proceed with the methods listed in the next paragraph; if not, determine feasible M&R alternatives as discussed in the Determine Feasible M&R Alternatives section below.

If the M&R strategy decision is to continue existing maintenance policy, the information in Tables 5 and 6 is used as a guide to select the appropriate maintenance method. These tables present feasible maintenance methods for each distress type at a given severity level. If the distress does not have any severity level, the letter "A" is used in place of the severity level. For example, for pumping distress in concrete pavements, the appropriate maintenance method (depending on existing conditions) could be crack sealing, joint sealing, and/or undersealing of the slabs.

Determine Feasible M&R Alternatives Based on Pavement Condition Evaluation Summary (Figure 14). The purpose of this step is to determine whether alternatives other than existing maintenance policy should be considered (e.g., overlay or recycling), and, if so, what specific feasible alternatives to consider. This is done by analyzing the section evaluation summary (Figure 14) for the pavement section under consideration. Based on this analysis, existing maintenance would usually be recommended except when one or more of the following conditions exists:

1. Long- or short-term rate of pavement deterioration is high.

2. Load-carrying capacity is deficient (indicated by a "Yes" rating on the summary sheet).

3. Load-associated distress accounts for a majority of the distress deduct value.

4. Surface roughness is rated major.

5. Skid resistance/hydroplaning potential is rated major.

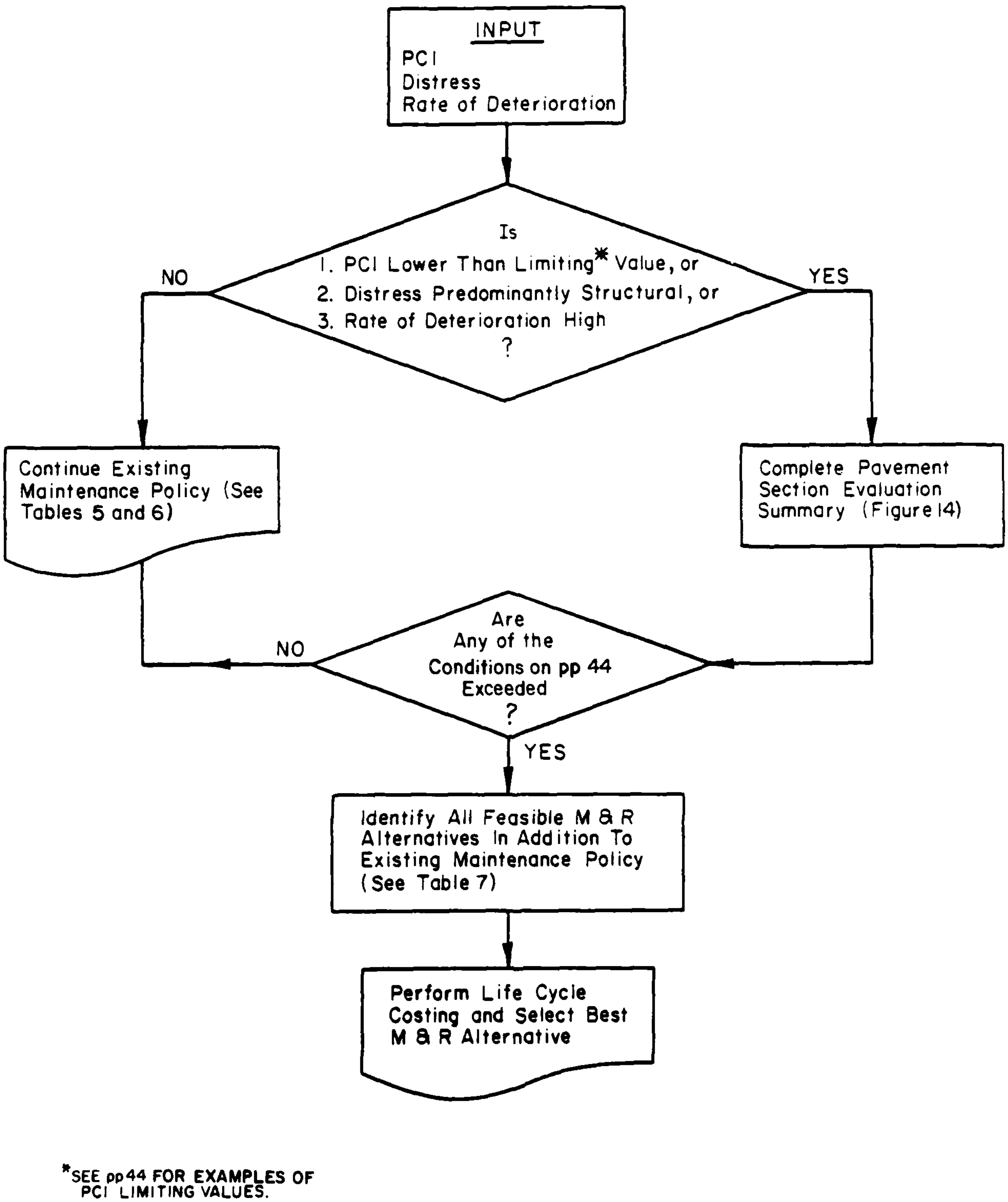


Figure 22. Process of determining M&R needs.

Table 5

Asphalt Concrete Pavement Distress Types and M&R Alternatives

Distress Type \ M&R Method	Do Nothing	Crack Seal	Partial Depth Patch	Full Depth Patch	Skin Patch	Pothole Filling	Apply Heat & Roll Sand	Apply Surface Seal Emulsion	Apply Rejuvenation	Apply Aggregate Seal Coat	Notes
1 Alligator Cracking			M,H	M,H				L	L		
2 Bleeding	L						L,M,H				
3 Block Cracking	L	L,M,H							L	L,M	
4 Bumps & Sags	L		M,H	M,H	M,H						
5 Corrugation	L		M,H	M,H							
6 Depression	L		M,H	M,H	M,H						
7 Edge Cracking	L	L,M	M,H	M,H							If predominant, apply shoulder seal, e.g., aggregate seal coat
8 Joint Reflective Cracking	L	L,M,H	H								
9 Lane/ Shoulder Drop Off	L										If predominant, level off shoulder and apply aggregate seal coat
10 Longitudinal Transverse Cracking	L	L,M,H	H					L	L	L,M	
11 Patching & Utility Cut	L	M	H*	H*							*Replace patch
12 Polished Aggregate	A									A	
13 Potholes			L	L,M,H		L,M,H					
14 Railroad Crossing	L				L,M,H						
15 Rutting	L		L,M,H	M,H	L,M,H						
16 Shoving	L		M,H								
17 Slippage Cracking	L	L	M,H								
18 Swell	L			M,H							
19 Weathering & Raveling	L		H					L,M	L	M,H	

Note: L = low severity; M = medium severity; H = high severity; A = has only one severity level.

Table 6

Jointed Concrete Pavement Distress Types and M&R Alternatives

Distress Type \ M&R Method	Do Nothing	Crack Sealing	Joint Sealing	Partial Depth Patch (Bonded)	Full Depth Patch	Slab Replacement	Under-Sealing	Grinding Slab	Slab Jack-Grout	Notes
21 Blow-ups				L*,M*	H*	H*				*Must provide expansion joint
22 Corner Break	L	L,M,H			M,H	H				
23 Divided Slab		L,M				M,H				
24 'D' Cracking	L	L*	L*	M,H	M,H	H				*If "D" cracks exist, seal all joints and cracks
25 Faulting	L					H		M,H	M,H	
26 Joint Seal Damage	L		M*,H							*Joint seal local areas
27 Lane/Shoulder Drop Off	L									If predominant, level off shoulder, apply aggregate seal coat
28 Linear Cracking	L	L,M,H		H*	H	H				*Allow crack to continue through patch except when using A-C
29 Large Patch & Utility Cuts	L	M		M*,H*	H*	H				*Replace patch
30 Small Patching	L	M		M*,H*	H*					*Replace patch
31 Polished Aggregate	A									If predominant, apply major or overall repair, e.g., overlay grooving
32 Popouts	A									
33 Pumping		A	A				A			
34 Punchouts	L	L,M			M,H	H				
35 Railroad Crossing	L									If M or H, level surface
36 Scaling/Map Cracks/Crazing	L			M,H	H					
37 Shrinkage Cracks	A									
38 Corner Spalling	L			L,M,H						
39 Joint Spalling	L		L	M,H	M,H*					*If caused by keyway failure, provide load transfer

Note: L = low severity; M = medium severity; H = high severity; A = has only one severity level.

6. Previous M&R applied is rated high.

7. A change in mission requires greater load-carrying capacity.

Table 7 lists most of the available overall repair procedures for asphalt and jointed concrete pavements.

All feasible alternatives should be identified based on a careful analysis of the section evaluation summary (Figure 14). Life-cycle cost analysis of the feasible alternatives will help rank the alternatives based on cost, and thus provide necessary information for selecting a cost-effective M&R alternative. A procedure for performing a life-cycle cost analysis is described in Chapter 5.

Establishing M&R Priorities

Criteria

The criteria for establishing priorities for pavement sections where routine M&R is required are different from those used for sections which need major M&R.

Routine M&R

Priorities for sections requiring routine M&R are a function of existing individual distress types and severities. A single method is usually applied for a given area, which may consist of many sections, rather than different M&R methods for one section. Distresses that may have a considerable negative effect on the section's operational performance are usually corrected first. For example, medium- and high-severity bumps, corrugations, potholes, and shoving would usually receive high priority.

Major M&R

Priorities among sections requiring major M&R are a function of the overall section condition, as reflected in the PCI, traffic, and management policies. For example, a decision might be made to repair all primary roads with a PCI of less than 60, secondary roads with a PCI of less than 50, and parking lots with a PCI of less than 40. The above PCI limits are provided as an example. Local conditions at military installations and commands will dictate what actual values to use.

Table 7

Types of Overall Repair for Jointed Concrete and Asphalt-Surfaced Pavements

Jointed-Concrete-Surfaced Pavements

1. Overlay with unbonded, partially bonded, or fully bonded Portland cement concrete (rigid overlay).

2. Overlay with all-bituminous or flexible overlay (nonrigid overlay).

3. Portland cement concrete pavement recycling* -- a process by which an existing Portland cement concrete pavement is processed into aggregate and sand sizes, then used in place of -- or in some instance with additions of -- conventional aggregates and sand, into a new mix and placed as a new Portland cement concrete pavement.

4. Pulverize existing surface in place, compact with heavy rollers, place aggregate on top, and overlay.

5. Replace keel section, i.e., remove central portion of pavement section (subjected to much higher percentage of traffic coverages than rest of pavement width) and replace with new pavement structure.

6. Reconstruct by removing existing pavement structure and replacing with a new one.

7. Grind off thin layer of surface if predominant distress is scaling or other surface distresses; overlay may or may not be applied.

8. Groove surface if poor skid resistance/hydroplaning potential is the main reason for overall M&R.

Asphalt- or Tar-Surfaced Pavements

1. Overlay with all-bituminous or flexible overlay.

2. Overlay with Portland cement concrete (rigid overlay).

3. Hot-mix asphalt pavement recycling* -- one of several methods where the major portion of the existing pavement structure (including in some cases, the underlying untreated base material) is removed, sized, and mixed hot with added asphalt cement at a central plant. Process may also include the addition of new aggregate and/or a softening agent. The finished product is a hot-mix asphalt base, binder, or surface course.

4. Cold-mix asphalt pavement recycling* -- one of several methods where the entire existing pavement structure (including, in some cases, the underlying untreated base material) is processed in place or removed and processed at a central plant. The materials are mixed cold and can be reused as an aggregate base, or asphalt and/or other materials can be added during mixing to provide a higher-strength base. This process requires use of an asphalt surface course or surface seal coat.

5. Asphalt pavement surface recycling* -- one of several methods where the surface of an existing asphalt pavement is planed, milled, or heated in place. In the latter case, the pavement may be scarified, remixed, relaid, and rolled. In addition, asphalts, softening agents, minimal amounts of new asphalt hot-mix, aggregates, or combinations of these may be added to obtain desirable mixture and surface characteristics. The finished product may be used as the final surface, or may, in some instances, be overlaid with an asphalt surface course.

6. Apply a porous friction course to restore skid resistance and eliminate hydroplaning potential.

7. Replace keel section, i.e., remove central portion of pavement feature (subjected to much higher percentage of traffic coverage than rest of pavement width) and replace with new pavement structure.

8. Reconstruct by removing existing pavement structure and replacing with a new one.

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* Federal Highway Administration, Initiation of National Experimental and Evaluation Program (NEEP) Project No. 22, Pavement Recycling ([FHWA] Notice N 5080.64, June 3, 1977).

5 PROCEDURE FOR PERFORMING ECONOMIC ANALYSIS OF M&R ALTERNATIVES

Introduction

The results of the pavement condition evaluation and the guidelines for M&R selection may indicate that the engineer should consider more than one M&R alternative. Selecting the best alternative often requires performing an economic analysis to compare the cost-effectiveness of all feasible alternatives. This chapter presents an economic analysis procedure which compares M&R alternatives based on present worth.

The Procedure

The procedure for determining the present worth of each M&R alternative consists of the steps described below.

Economic Analysis Period

Select an economic analysis period (in years). The period generally used in pavement analysis ranges from 10 to 30 years, depending on future use of the section (abandonment, change of mission, etc.). The analysis period should be the same for all alternatives.

Interest and Inflation Rates

Select interest and inflation rates to be used in calculating the present cost. This is a very important step, since the selected rates have a significant impact on the ranking of the alternatives with respect to their present worth. The selection of the rates, therefore, should be based on policies and guidelines established by the office of the Secretary of Defense. It should also be noted that the inflation rate used to compute present worth is the differential inflation rate, i.e., the rate of cost increase above the general inflation rate. Therefore, if the cost increase of a specific item is in line with the cost growth experienced by the economy, the differential inflation rate is assumed to be zero. For example, if the cost of M&R for asphalt pavements is increasing at an annual inflation rate of 14 percent while the general inflation rate is 8 percent, the differential inflation is 6 percent.

Annual Cost Estimation

The annual cost for each M&R alternative for every year work is planned during the analysis period should be estimated. The cost of rehabilitation at the end of the analysis period for each M&R alternative should also be determined so that the pavement will be equivalent to a new pavement. All cost estimates should be based on current prices.

Present Worth Computation

The present worth for each M&R alternative is computed as follows:

$$\text{Present worth} = [\sum_{i=1}^{n} C_i \times f_i] + R \times f_n \qquad \text{[Eq 5]}$$

where

n = number of years in the analysis period
C_i = M&R cost for year i based on current prices
f_i = present worth factor for i^{th} year that is a function of the interest rate (r_t), and inflation rate (r_f)

$$f_i = \left(\frac{1 + r_f}{1 + r_t}\right)^i$$

R = cost of rehabilitation at the end of the analysis period so that the pavement will be equivalent to a new pavement. The cost is computed based on current prices.
f_n = present worth factor at the end of the analysis period

$$f_n = \left(\frac{1 + r_f}{1 + r_t}\right)^n$$

The physical interpretation of Eq 5 is that the present worth of any M&R alternative is the sum of all the discounted M&R costs during the analysis period plus the cost of rehabilitating the pavement at the end of the analysis period (so that it will be equivalent to a new pavement), discounted to the present. After the steps described are completed for each M&R alternative, the present worths of all M&R alternatives are compared to help the pavement engineer select the most cost-effective repair alternative.

Predictions and Assumptions

A number of predictions and assumptions must be made to perform the economic analysis. The engineer must therefore use judgment in selecting the best inputs.

Computations

If automated PAVER is used, the present worth computations are performed by the computer (see Figure 36 in Chapter 7 for an example computer output). Otherwise, the format shown in Figure 23 has been devised for convenience when performing the computations by hand. Figure 24 is an example computation for one M&R alternative.

M & R ALTERNATIVE ____

____

ANALYSIS PERIOD ________ YEARS   INTEREST RATE _____ %

DIFFERENTIAL INFLATION RATE _____ %

YEAR	M & R WORK DESCRIPTION	COST $	f	PRESENT WORTH $
			TOTAL	$

Figure 23. Present worth computation form.

M & R ALTERNATIVE Patch Joints Then Overlay With 2 inch Asphalt Concrete

ANALYSIS PERIOD 20 YEARS INTEREST RATE 10 %

DIFFERENTIAL INFLATION RATE 6 %

YEAR	M & R WORK DESCRIPTION	COST $	f	PRESENT WORTH $
1980	Patch Joints	14,410	1.0	14,410
1980	Overlay With 2 in. A.C.	6,000	1.0	6,000
1985	Fill Cracks	1,000	0.831	831
1990	Fill Cracks	1,500	0.690	1,036
1995	Fill Cracks	1,500	0.574	861
2000	Replace 2 in. A.C. Using Cold Milling	12,000	0.477	5,721
			TOTAL	$28,859

Figure 24. Example present worth computation of an M&R alternative.

6 DATA MANAGEMENT -- MANUAL PAVER SYSTEM

Introduction

Chapters 2 through 5 discussed the data collection and analysis procedures which constitute the pavement management system. To use this system, it is necessary to store data in a usable manner; this data storage can be achieved by using either a computer system or a manual recordkeeping system. If a manual system is used, initial data storage is usually small and handled easily. The more the management system is used, the more data that must be collected and stored. Thus, the manual data storage system described in this chapter has been designed so conversion to a computer data storage system will not be complex or time-consuming.

Manual System Description

The manual data storage system stores collected data in a card format. The cards are similar to those used in a computer data storage system (Chapter 7). The manual data storage system consists of eight cards, each containing pertinent information on the pavement network. Two cards refer to the pavement branches; the remaining six cards refer to given sections within each branch of the system. Each of the cards is described below and is accompanied by an example card. Blank cards for reproduction are given at the end of this chapter.

Card 1 -- Branch Identification Summary

This card lists all branches in the pavement network, thereby providing an inventory of all network branches and sections. An example card is shown in Figure 25. As shown, the card heading contains the installation code, name, and location. Space is also provided for the initial date, updates, and the total number of branches in the network. The next section of the card provides space to list each branch of the network; the branch code, name, use, number of sections, and total area are recorded for each branch. The list of branches can be arranged alphabetically, by quadrants of the installation, or in any other orderly fashion.

Card 2 -- Section Identification Record

This card identifies each pavement section and its use. One card is developed for each section in the pavement network. As shown in Figure 26, the card contains space for installation name, date, branch name, section area, number of sample units, section number, and identification of the section as belonging to real property or family housing areas. General traffic information is given as vehicle type and use (primary, secondary, etc.). Space is also provided for a sketch of the area; this sketch should contain at least the following:

1. Section length dimension, width, or other measurements needed to calculate irregularly shaped areas.

CARD 1 - - BRANCH IDENTIFICATION SUMMARY

Sheet 1 of ___

Installation			Date			Up Dates						Total No of Branches
Code	Name	Location	Mo	Da	Yr	1			4			
99999	Fort Z	Home II	10	1	79	2			5			3

Branch Code					Branch Name	Branch Use	Number of Sections	Branch Area Sq Yd
I	4	7	3	5	Marshall Ave.	Road way	5	1388
I	2	9	4	6	Platoon Str.	Road way	3	735
P	L	3	2	1	Parking Bldg. 321	Parking (cars)	1	700

Remarks: ___

Figure 25. Example branch identification summary card.

2. Section limits clearly defined to indicate intersections with other branches or sections.

3. All shoulder information and secondary structure information, including location and number of manholes, catch basins, etc. (Location of these structures is important since they can affect maintenance and/or rehabilitation practices.)

4. Sample units in the section. (Locating sample units will help when verifying inspection results and planning future inspections.)

Information contained on Card 2 can be used to plan inspection and estimate maintenance or rehabilitation costs. It is important to note that the identification of real property and family housing areas is essential, since funds for each of these areas are allocated differently.

Card 3 -- Section Pavement Structure Record

This card (Figure 27) is designed to enable identification of existing structural layers of pavement. The information contained on this card is important when evaluating the pavement load-carrying capacity and determining feasible M&R alternatives. Card 3 is divided into three areas: initial construction, overlays, and surface treatment.

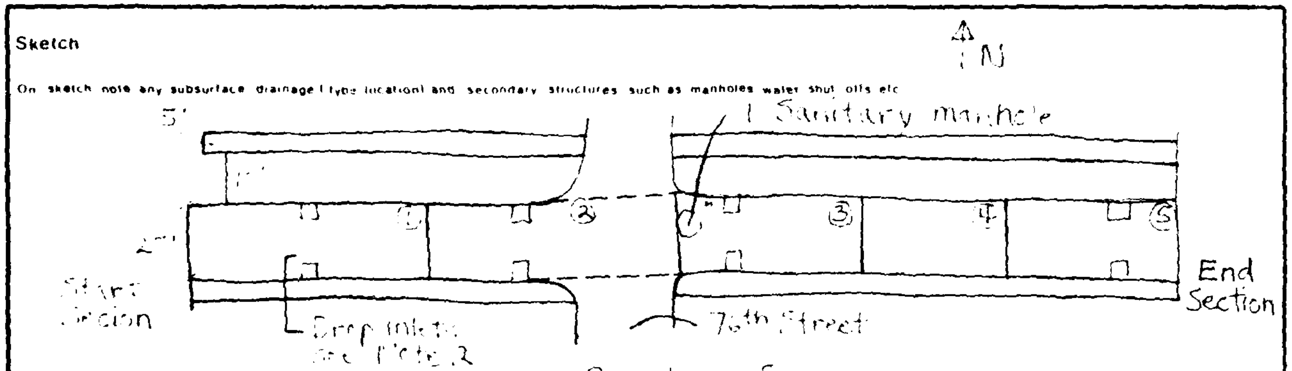
CARD 2 - - SECTION IDENTIFICATION RECORD

Installation Name	Date	Branch Name	Section Area	No of Sample Units	Section No
Fort ≠	1 2 77	Marshall Ave.	25 ft x 500 ft 1383 sq yd	5	1

Traffic Types And Uses				General Information		
				Curb And Gutter	Sidewalks	Surface Type
O Aircraft O Fixed Wing O Rotary Wing	O Runway O Taxiway O Parking or Pads O Apron O Other	⊗ Vehicular ⊗ Real Property O Family Housing	⊗ Primary O Secondary O Tertiary O Parking · Storage O Other	⊗ Left ⊗ Right O None	⊗ Left ____ ft ⊗ Right ____ ft O None ____	O PCC ⊗ AC O Surface Treatment O Other

Sketch

On sketch note any subsurface drainage (type location) and secondary structures such as manholes water shut offs etc



Notes:
1. 5 Sample Units @ 100'. Marshall Street Structure. ... the intersection.
2. Curb Drop Inlets - 4 (total 4 in section). Mainline is on South side of pvmt cross over pipe from North Inlet. Inlets are in conc. curb.
3. No Subsurface Drainage.
4. No Shoulders

Figure 26. Example section identification record card.

CARD 3 - - SECTION PAVEMENT STRUCTURE RECORD

Installation Name	Date			Branch Name	Section Number
Fort Z	10	10	79	Marshall Street	1

		Material	Material Code			Thickness (in.)	Date Const	Location (If less than entire section)* From	To
Surface Treatment	Surf. Treat. (3)								
	Surf. Treat. (2)								
	Surf. Treat. (1)								
Overlays	Overlay (3)								
	Overlay (2)								
	Overlay (1)	Asphalt Con. Mix C.	1	2	0	1.5	10/78		

		Material	Material Code			Thickness (in.)	Date Const.	Comments
Initial Construction	Surface	Asphalt Conc.	1	2	0	.5	10/78 6/60	Surface milled 1.5 inches 10/78 .5 inches original remaining
	Leveling	Asphalt Conc.	1	2	0	2.0	6/60	
	Base	Crushed Stone	3	1	1	8.0	5/60	
	Subbase							
	Select							
	Compacted Subgrade	Silty Clay	3	4	5	12	5/60	
	Natural Subgrade	Silty Clay	3	4	5	—	—	

*New Section of Branch Must Then be Identified

Figure 27. Example section pavement structure record card.

Information referring to the original construction may not always be obtainable. However, if repair work is performed in the section, the thickness and type of material should be recorded. The material codes in Table 8 should be used, when possible.

The top portion of the card provides space for recording overlays or surface treatments applied to a given section. Space is also provided to record the location of placement if the entire section is not repaired. It is important to note that if an entire section is not overlaid, a new section must be defined. Also, if a section's surface is removed by rotomilling, the overlay should be recorded and the milling noted in the comments portion of the card.

The original surface thickness should also be reduced by the appropriate amount. In the event the surface is heater scarified and recompacted, this should be recorded as a surface treatment and noted in the comments portion of the card.

Card 4 -- Section Materials Properties Record

This card (Figure 28) stores information on the material properties of the pavement section. It should contain any available test data on each pavement layer. (Typical tests for each pavement layer are listed in Table 9.) This card, in conjunction with the Pavement Structure Card, can be used to evaluate the load-carrying capacity of the section. Also, the material properties information and condition record can provide feedback on the performance of different paving materials.

Card 5 -- Section Traffic Record

The Section Traffic Record Card stores information on the type and volume of traffic using the facility. A method for recording traffic on roads and streets is provided; however, traffic on branches such as parking areas and storage areas is recorded free-form in the space at the bottom of the card. In general, this card is completed in the following manner:

The date of the traffic survey and the volume index of each type of traffic observed are recorded each time a survey of traffic on roads and streets is taken. The index for each type of traffic is given in Table 10. The volume index for each type of traffic is based on the annual operations per lane per day for that type of traffic. As an example, consider the following data:

Type of Traffic Using the Pavement Section	Volume per Lane per Day
Passenger, panel, and pickups	2500
Two-axle trucks and buses	85
Trucks with three or more axles	15

Using these data, the volume indices for each traffic type can be determined from Table 10 as follows:

1. Locate traffic-type column. For example, use column "a" for passenger, panel, and pickups.

Table 8

Material Codes

100 Surface Materials*

110 Portland Cement Concrete
- 111 plain
- 112 reinforced concrete pavements (RCP)
- 113 continuously reinforced concrete pavement (CRCP)
- 114 prestressed
- 115 fibrous

120 Asphalt Concrete

130 Road Mix Bituminous Surface

140 Sand-Asphalt
- 141 plant mix
- 142 road mix

150 Surface Treatments
- 151 single-layer aggregate seal
- 152 double-layer aggregate seal
- 153 three- or more layer aggregate seal
- 154 sand seal
- 155 slurry seal
- 156 fog seal
- 157 asphalt rubber chip
- 158 fabric
- 159 dust layering

160 Preformed Joint Fillers
- 161 bituminous fiber
- 162 cork
- 163 self-expanding cork
- 164 self-expanding rubber
- 165 sponge rubber
- 166 closed cell plastic

170 Joint and Crack Sealers
- 171 hot-poured
- 172 cold-poured

180 Others

200 Treated or Stabilized Materials

210 Cement Treated
- 211 gravel and crushed stone
- 212 sand
- 213 silt and clay

220 Lime-Flyash Treated
- 221 gravel and crushed stone
- 222 sand
- 223 slag

230 Lime-Treated Fine-Grained Soil

240 Asphalt-Treated Plant Mix
- 241 crushed stone
- 242 gravel
- 243 sand

250 Asphalt-Treated Road Mix
- 251 crushed stone
- 252 gravel
- 253 sand

280 Others

300 Untreated Materials

310 Crushed Stone
- 311 well-graded
- 312 poorly graded (one-sized)
- 313 high fines content

320 Gravel
- 321 well-graded
- 322 poorly graded
- 323 high fines content

340 Fine-Grained Soils
- 341 sandy silt
- 342 silt
- 348 organic clay

380 Others

---

*For unpaved roads, refer to treated or untreated materials list for identification purposes.

CARD 4 -- SECTION MATERIALS PROPERTIES RECORD

Installation Name	Date			Branch Name	Section Number
Fort Z	10	1	79	Marshall Ave.	1

Pavement Layer	Material Properties	Value/Unit	Comments
Overlay 1	Tests 1978 Marshall Stability	1600 Lbs	
	Flow	11 .01 ins.	
	Air Voids	4%	
	Unit Weight	141 pcf	
	Insitu Density	138 pcf	Avg. of field tests
Surface	No Properties Available		
Leveling	" "	"	
Base Course	CBR	60%	Tested Insitu 10/78
	Insitu Moisture	12%	
Subgrade	CBR	15%	Tested Insitu 9/75
	Insitu Dry Density	116 pcf	
	Insitu Moisture	20%	

Figure 28. Example section materials properties record card.

Table 9

Typical Layer Materials Properties

1. Asphalt Concrete (Surface, Leveling, Base)	
Marshall stability (pounds)	Asphalt content (%)
Flow (0.01 inch)	Unit weight (pounds/cubic foot)
air voids (%)	Asphalt penetration (millimeters x 10^{-1})
2. Portland Cement Concrete (PCC)	
Modulus of rupture (pounds/square inch)	
Compressive strength (pounds/square inch)	
Entrained air (%)	
Water/cement ratio (gallons/sack)	
3. Base-Subbase Materials	
k-value (pounds/square inch)	
CBR (%)	
In-situ dry density (% of optimum)	
In-situ moisture content	
4. Subgrade	
Unified classification	Liquid limit
CBR (%)	Optimum moisture control (%)
k-value (pounds/square inch)	In-situ moisture content (%)
Plasticity index	In-situ dry density (% of optimum)

2. Look down the traffic-type column to find the box corresponding to volume per lane per day.

3. Look horizontally (to the far right) to determine the volume index.

The volume indices for each type of traffic should be recorded on the Section Traffic Record Card as shown in Figure 29.

Space is provided for describing the type and volume of traffic using facilities other than roads. For example, if the pavement section being considered is a parking lot, the description of traffic can be, "The dominant type of vehicle using the parking lot is passenger cars, averaging 12 hours per day." This information is used when evaluating the existing pavement section or when designing a new cross-section.

Card 6 -- Section Condition Record

The Section Condition Record Card stores data obtained from the condition survey of the section's sample units and summarizes the distress found in each section. As shown in Figure 30, both the average PCI of the sample units and

Table 10

Traffic Volume Index for Roads

TRAFFIC TYPE

a	b	c	d	e	f	VOLUME INDEX
ANNUAL AVERAGE OPERATION PER LANE PER DAY						
NONE	NONE	NONE	NONE	NONE	NONE	0
LESS THAN 100	LESS THAN 10	LESS THAN 10	LESS THAN 1	LESS THAN 1	LESS THAN 1	1
100-499	10-49	10-49	1-4	1-4	1-4	2
500-999	50-199	50-199	5-9	5-9	4-9	3
1000-1999	200-499	200-499	10-19	10-19	10-19	4
2000-3999	500-999	500-999	20-49	19-49	20-39	5
4000-5999	1000-1499	1000-1499	50-99	50-99	40-59	6
6000-7999	1500-1999	1500-1999	100-199	100-149	60-79	7
8000-9999	2000-2499	2000-2499	200-399	150-199	80-99	8
MORE THAN 10,000	MORE THAN 2500	MORE THAN 2500	MORE THAN 400	MORE THAN 200	MORE THAN 100	9

[a] Passenger, panel and pickups

[b] Two axle trucks and buses; also half-or full-track vehicles less than 20 kip, and fork lift trucks less than 5 kip.

[c] Trucks with three or more axles. Also half- or full-track vehicles 20-40 kip, and forklift trucks 5-10 kip.

[d] 60-kip track vehicles and/or 15 kip forklifts. Number of operations per lane per day for tracked vehicles 40-60 kip and/or forklift trucks 10-15 kip.

[e] 90 kip track vehicles and/or 20 kip forklifts.

[f] 120 kip track vehicles and/or 35 kip forklifts.

DATE OF SURVEY	9/1973											
TRAFFIC TYPE	a	b	c	d	e	f	a	b	c	d	e	f
VOLUME INDEX	5	3	2	0	0	0						

CARD 5 - - SECTION TRAFFIC RECORD

Installation Name	Date			Branch Name	Section Number
Fort Z	10	1	79	Marshall Ave.	1

Roads or Streets																								
Date of Survey	9/78						8/79																	
Traffic Type	a	b	c	d	e	f	a	b	c	d	e	f	a	b	c	d	e	f	a	b	c	d	e	f
Volume Index	5	3	2	0	0	0	6	4	1	0	0	0												

Parking Lots - Airfields - Other	
Date of Survey	Description

Figure 29. Example section traffic record card.

CARD 6 - - SECTION CONDITION RECORD

Installation Name	Branch Name	Date			Section Number
FORT Z	MARSHALL AVENUE	10	1	79	1

Average PCI 70 Condition Rating GOOD

Ride Quality G X F ___ P ___ Safety G X F ___ P ___ Drainage G X F ___ P ___

Total No. of Sample Units 5 No. of Random Units Surveyed 5

No of Additional Units Surveyed 0

PCI Range 20 Minimum of Units to be Surveyed 5

Pavement Type ⊗AC ○PCC

Section Area 25 ft x 500 ft
1388 sq yd.

Section Distress Data ○ Extrapolated Quanities ⊗ Actual Quantities

Distress Type	Severity Level	Quantity	Section Density	Deduct Value	Comments
1	L	30	.24	4	
1	M	80	.64	17	
7	M	300	2.4	12	
15	L	80	.64	14	RUTS OCCUR IN CONJUNCTION WITH MEDIUM ALLIGATOR CRACKS (1M)
			Total	47	

Percent Deducts Structural Related 75 Enviromental ___ Other 25

Figure 30. Example section condition record card.

the appropriate condition rating are recorded. Next, overall ratings (ride quality, safety, and drainage) are recorded; these ratings are for general information only, since the PCI accounts for each of these factors through distress types.

If the section is inspected by sampling, the number of random and additional units surveyed is recorded. If all sample units are surveyed, the number is recorded as random units; the total number of units in the section should also be recorded. The PCI range is computed by subtracting the lowest sample unit PCI from the highest sample unit PCI, and the minimum number of sample units to be surveyed is determined as described in Chapter 3.

If the minimum number of sample units required is greater than the number of random units surveyed, more units must be selected at random and surveyed.

Once it has been determined that a sufficient number of samples has been surveyed, the section distress data portion of the card can be completed. If inspection by sampling was used, the circle next to extrapolated quantities should be checked; if all sample units were inspected, the actual quantities circled should be checked.

The pavement type should be identified by checking the appropriate circle. To complete this portion of the card, the distress data from the sample unit inspection sheets must be compiled.

If actual quantities are used (i.e., the entire section was inspected), the section's values are found by totaling the quantity of each distress type and severity level. The section density and deduct values are then computed as normally done for a sample unit (see Chapter 3, the Asphalt Pavement Sample Unit section for asphalt pavements and the Jointed Concrete Sample Unit section for concrete pavements).

(b) If the section was inspected by sampling, the extrapolated distress quantity for the section is computed as explained in Chapter 3 (p 31). The section density and deduct values are then computed as normally done for a sample unit.

Distress information, recorded as described above, can be used to evaluate M&R requirements and to provide quantities of repair for cost estimates. It is very important to note that the deduct values determined from these data cannot be used to compute the PCI of the section.

The PCI of the section is the average of the sample unit PCIs. Space is provided at the bottom of the card to record the percent of deducts related to structural, environmental, or other conditions; these values are used when performing the section evaluation described in Chapter 5.

Card 7 -- Branch M&R Requirements

This card (Figure 31) stores information on required M&R activities; it is completed by using information already recorded on Cards 2 through 6. (For a detailed explanation of how to determine M&R requirements, see Chapter 4.)

CARD 7 - - BRANCH MAINTENANCE AND REPAIR REQUIREMENTS Sheet 1 of 1

Installation Name	Date	Branch Name	Total No of Sections
FORT Z	10/1/79	Marshall Ave.	1

Work Class : M - Maintenance R - Repair C New Constructio Location : R Roadway PL Parking Lot A - Airfield O - Other

Section No	Work Description	Work Class	Loc	Thickness, inches	Quantity/Unit	Est Cost	Priority	Date Completed, M/Y
1	*Deep Patch Med. Allig Cracks	M	R	6	10 sq. yd.	$100.00	1	
"	Crack Fill Med. Edge Cracks	M	R	—	300 Lin. ft.	450	2	

Remarks * Patching of Med. Alligator Cracks Will Eliminate Existing Ruts

Figure 31. Example branch M&R requirements card.

For each branch of the pavement network, a Branch M&R Requirements Card (or cards) should be completed. For each section of a branch, maintenance activities, work class, location, thickness (patches, overlays), quantity of repair, and estimated cost are recorded. A column at the end of the card is used to set priorities for maintenance activities.

The information on the Branch M&R Requirements Card(s) may change frequently. For example, when an activity has been completed, other priorities may change. Thus, when an activity is completed, the date of completion must be recorded. Other priorities can be updated at this time.

Since the information on the Branch M&R Requirements Card(s) changes frequently, a new card(s) may be made when necessary. However, information on completed M&R activities should always be transferred to Card 8 as a permanent record.

Card 8 -- Section M&R Record

The information on Card 8 (Figure 32) can be compiled from Card 7 and as-built records. A separate card is kept for each section; this allows the expenditures for maintenance of each section to be monitored. This type of information may be valuable when determining M&R requirements or when performing economic analyses on other sections. The information on Card 8 is very similar to that kept on Card 7, except that the date of M&R is listed for each activity and the cost should be the actual cost of M&R rather than an estimate.

Manual Recordkeeping System -- General

The manual recordkeeping system consists primarily of eight cards that are used for information storage. To use data efficiently, this information must be stored in an orderly fashion. Figure 33 is an example of such a system; it can be described as follows:

Inventory

One folder stores the network inventory. This is the information recorded on Card 1 -- Branch Identification Summary.

Branch Identification Folder

One folder stores branch identification information. This folder serves as a heading card and as the storage slot for Card 7 -- M&R Requirements. This allows anticipated maintenance activities for each section of the branch to be stored in one location. The branch identification cards should be filed in the order shown on the Branch Identification Summary Card.

Branch Sections

After the Branch Identification Summary Card, a series of file folders should be provided for each section of the branch. One folder each is provided for Cards 2, 3, 4, 5, 6, and 8. These cards contain basic information on the section.

CARD 8 - - SECTION MAINTENANCE AND REPAIR RECORD

Sheet 1 of 1

Installation Name	Date			Branch Name	Section Number
	Mo	Da	Yr		
FORT Z	11	1	77	Marshall Ave.	1

Work Performed					
Date of M&R	Description of Work	Location	Thickness	Quantity/Unit	Cost
10/20/79	Deep Patches	Wheel Paths Sample Units 1,3,4,5	6 ins.	15 sq. yds.	$150.00
10/22/79	Crack Filling	Edges Sample Units 1-3	—	300 Lin. ft.	$400.00

Remarks

Figure 32. Example section M&R record card.

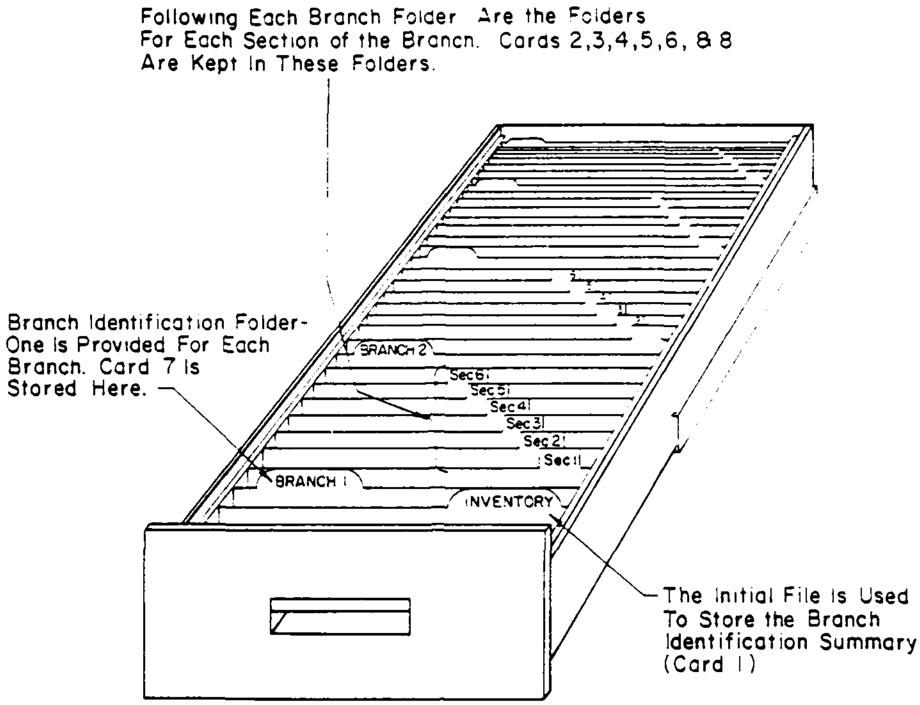


Figure 33. Example of a filing sequence for a manual recordkeeping system.

Inspection Sheets

Field survey data on the sample unit inspection sheets should be retained. Since this information is included on the Section Condition Record Card, it is not necessary to keep the inspection sheets in the filing system. However, these sheets can be used to verify inspection data.

Record Upkeep

Once the initial division of the pavement network into branches and sections has been completed, the filing system can be started. As the initial inspections take place, the information on Cards 2 through 6 can be compiled. And as branches are completed, data analyses can begin (Chapter 5).

Updating Data Cards

Data cards must be updated once maintenance activities begin. If overlays or surface treatments are applied, the Section Pavement Structure Record Card (Card 3) must be updated. Also, as work is completed, information from the Branch M&R Requirements Card (Card 7) must be transferred to the Section M&R Record Card (Card 8). Performance of maintenance activities will also change the condition of the section; thus, the condition survey should also be updated.

Updating of Condition Survey

If a section receives no maintenance, the condition survey should be updated based on the rate of deterioration. Initially, this rate can be estimated by briefly inspecting the section to observe changes in distress types or severities. Until data are compiled, sections should be reviewed at least annually to observe this change in condition. Once the rate of deterioration is determined, sections with high rates may be inspected at more infrequent intervals. If the filing system is updated continuously as work is performed and inspections are completed, it should not be necessary for the pavement engineer to perform a condition survey of the entire system all at one time.

Economic Analysis

Any economic analysis performed to determine M&R strategies for given sections should also be filed with the section information cards.

Extra Forms

Appendix C provides blank copies of the forms used in Figures 25 through 32 (Cards 1 through 8).

7 DATA MANAGEMENT -- COMPUTERIZED PAVER SYSTEM

Purpose

Computerized Data Management

The manual data management system described in Chapter 6 is a systematic way of recording and storing information needed for effective pavement maintenance management. However, for medium- to large-sized installations, the number of record cards can increase to the point where it is very time-consuming to manually search, sort, and compile information for various maintenance management applications. A computerized system solves this problem by automatically performing data retrieval, sorting, and compilation. In addition, the computer performs a number of calculations which the user would otherwise have to do manually. It also performs other useful calculations that the user would not do manually due to time availability.

Description of System

This chapter briefly describes the computerized PAVER. Specific user instructions for the PAVER system may be obtained from the assigned responsible agency -- the U.S. Army Facilities Engineering Support Agency (FESA), Fort Belvoir, VA.

Recommended Cases for Use of Computerized PAVER

Generally, the computerized system is recommended for expediency of data handling and report generation. It may become necessary, however, for pavement networks with a large number of pavement sections (more than 100). This is only a general guideline, however; if the choice is not clear-cut, it is always possible to set up a manual system and then later convert to a computerized system.

System Description

PAVER is operated via a desk-sized computer terminal normally located in the Buildings and Grounds Division. This terminal sends and receives information from a central computer via standard telephone lines. The user stores information about the pavement network in the computer by typing in data on the terminal or by having data keypunched and read in through a card reader. The user retrieves information from the computer by typing in commands which cause reports to be printed on the terminal.

PAVER Data Input/Update Forms

The data stored in the computer are virtually the same as those recorded on the record cards of the manual system. To make these data machine-readable, special input/update forms are used. By using an ADD/CHANGE/DELETE code, each input form can be used to store new information in the computer or to make changes or deletions to information that has already been stored. An

outstanding feature of the PAVER input/update program is that the PCI and extrapolated distress data for the pavement section are computed as the condition survey data are input or revised.

PAVER Report Outputs

There are two types of PAVER reports: the Writer Reports and the Computation Reports.

Writer Reports. Writer reports are preformatted reports generated by the PAVER Data Base Manager feature called the report writer, which sorts through PAVER stored information to meet specific user requirements at the time of report generation. There are several such reports available, including those for generating inspection results, pavement ranking, pavement inventory, pavement structure, work required, and work completed history. The formats of these reports can be modified or reformatted per a user request in a very short time (usually a few weeks). An example of a pavement inspection report is shown in Figure 34. An example of pavement ranking in an increasing order of PCI is shown in Figure 35.

Computation reports. Computation reports are special reports that require further processing (computations) of the data stored in PAVER and/or new data provided by the user. One of the currently available reports develops routine M&R requirements based on stored pavement distress data and the engineer maintenance policy (which can be stored in PAVER). An example output is shown in Figure 36. Another available report computes the present worth of any M&R alternative using the economic analysis procedure presented in Chapter 5. An example output is shown in Figure 37. Other computation reports include current and projected pavement condition distribution, projected budget requirements for a given condition standard, inspection schedules, and condition history. An example output from the projected pavement condition distribution report is shown in Figure 38.

System Use and Update

PAVER should be used and updated in a manner similar to the manual system. Some of the computer reports can be used to provide periodic assignments to the pavement maintenance crew or to generate work to be done by contract. Other reports can be used to communicate pavement condition and maintenance requirements to higher management. It is important, however, that M&R activities completed be input to PAVER. PAVER will automatically delete the corresponding work requirement (if any) and will store the work completed as work history.

Pavement Inspection Information

As a pavement section is inspected, information should be input to PAVER; PAVER will not delete the results from any previous inspection of the section unless specifically required to do so by the user. Therefore, pavement condition information over a period of time will be readily available.

REPORT DATE- 08/10/81 PAVEMENT INSPECTION

INSTALLATION NUMBER = 051215 FORT EUSTIS

BRANCH NAME - DICKMAN STREET SECTION LENGTH - 414 LF
BRANCH NUMBER - IDICK SECTION WIDTH - 21 LF
SECTION NUMBER - 01 SECTION AREA - 966 SY

INSPECTION DATE - 12/03/79 PCI= 53 RATING= FAIR
CONDITION- RIDING-C1 SAFETY-C1 DRAINAGE-C1 SHOULDERS-C1 OVERALL-C1

TOTAL NUMBER OF SAMPLES IN SECTION= 4
NUMBER OF SAMPLES SURVEYED= 4
RECOMMEND ALL SAMPLE UNITS TO BE SURVEYED.

EXTRAPOLATED DISTRESS QUANTITIES FOR SECTION-

DISTRESS TYPE	SEVERITY	QUANTITY	DENSITY-PCT	DEDUCT-VALUE
ALLIGATOR CR	HIGH	15 SF	0.17	14.2
ALLIGATOR CR	LOW	680 SF	7.82	29.5
ALLIGATOR CR	MEDIUM	60 SF	0.69	17.7
BLEEDING	LOW	8 LF	0.09	0.0
DEPRESSION	LOW	18 SF	0.20	4.0
EDGE CR	HIGH	4 LF	0.04	7.4
LONG/TRANS CR	LOW	287 LF	3.30	7.6
PATCH/UTIL CUT	LOW	100 SF	1.15	2.4
PATCH/UTIL CUT	MEDIUM	50 SF	0.57	7.0
POTHOLE	HIGH	4 NMBR	0.04	40.2
RUTTING	LOW	10 SF	0.11	1.0

Figure 34. Example of inspection report.

REPORT DATE- 08/06/81 PCI REPORT

INSTALLATION NUMBER = 051215 FORT EUSTIS

BRANCH NUMBER	BRANCH USE	SECTION NUMBER	PCI	RATING	SURFACE TYPE	SECTION AREA/SY	PAVEMENT RANK
IMONR	ROADWAY	01	50	FAIR	AC	608	TERTIARY
	11/27/79	[FROM] NR BLDG 832			[TO] W EDGE LUCAS PL		
IBUTN	ROADWAY	02	52	FAIR	AC	392	TERTIARY
	11/08/79	[FROM] E EDGE PATTON AVE			[TO] W EDGE PERSHING AVE		
IMULB	ROADWAY	04	52	FAIR	AC	1683	TERTIARY
	02/20/80	[FROM] NR BLDG 3905			[TO] END OF PAVEMENT		
I12ST	ROADWAY	03	52	FAIR	AC	399	TERTIARY
	02/11/81	[FROM] E'LY EDGE PATTON			[TO] W'LY EDGE LEE BLVD		
IDICK	ROADWAY	01	53	FAIR	AC	966	TERTIARY
	12/03/79	[FROM] S EDGE LEE BLVD			[TO] N EDGE TYLER AVE		
IREIN	ROADWAY	01	53	FAIR	AC	694	TERTIARY
	02/11/81	[FROM] E'LY EDGE MADISON			[TO] W'LY EDGE WILSON LN		
IMONR	ROADWAY	05	54	FAIR	PCC	1622	SECONDARY
	12/05/79	[FROM] S EDGE TAYLOR AVE			[TO] N EDGE BUNDY ST		
IWILN	ROADWAY	01	55	FAIR	AC	1670	TERTIARY
	11/29/79	[FROM] PERSHING AVE			[TO] JUST BEYOND JURASIN		
IBALK	ROADWAY	01	56	GOOD	AC	5155	TERTIARY
	02/04/80	[FROM] E EDGE HARRISON RD			[TO] W EDGE MULBRY IS RD		
ISPIF	ROADWAY	01	56	GOOD	PCC	1391	TERTIARY
	01/12/80	[FROM] BLDG 408			[TO] BLDG 414		
ITINC	ROADWAY	01	56	GOOD	AC	3068	TERTIARY
	01/09/80	[FROM] W ED MADI BLDG 2783			[TO] TINC02 BLDG 2798		
IMULB	ROADWAY	02	57	GOOD	AC	12551	PRIMARY
	02/20/80	[FROM] N EDGE WILSON AVE			[TO] ENTR PINES GOLF CLB		
IKELL	ROADWAY	01	58	GOOD	AC	3378	TERTIARY
	10/30/79	[FROM] S'LY EDGE MONROE			[TO] ROD & GUN CLUB		
I06ST	ROADWAY	01	58	GOOD	AC	2020	TERTIARY
	11/09/79	[FROM] E'LE EDGE BULLARD			[TO] W'LY EDGE JACKSON		
IWRIG	ROADWAY	01	60	GOOD	PCC	1371	TERTIARY
	10/18/79	[FROM] E'LY EDGE WASH NO			[TO] W'LY EDGE WALKER ST		
IKERR	ROADWAY	01	63	GOOD	AC	4897	TERTIARY
	01/16/80	[FROM] N'LY EDGE LEE BLVD			[TO] BLDG 425 3RD PORT		
I12ST	ROADWAY	03	63	GOOD	AC	399	TERTIARY
	12/14/79	[FROM] E'LY EDGE PATTON			[TO] W'LY EDGE LEE BLVD		
I13ST	ROADWAY	02	63	GOOD	AC	1038	TERTIARY
	12/14/79	[FROM] E'LY EDGE JACKSON			[TO] W'LY EDGE PATTON		
IGAFF	ROADWAY	01	64	GOOD	PCC	2152	TERTIARY
	10/22/79	[FROM] N EDGE MONROE AVE			[TO] S EDGE LEE BLVD		
IWASN	ROADWAY	03	64	GOOD	AC	4000	PRIMARY
	11/08/79	[FROM] S'LY SIDE HINES CIR			[TO] CENTER OF SOMERVELL		
ILEEB	ROADWAY	05	65	GOOD	AC	7688	PRIMARY
	11/15/79	[FROM] W'LY SIDE ANDERSON			[TO] HINES CIR		
IWASN	ROADWAY	05	65	GOOD	PCC	4453	SECONDARY
	11/09/79	[FROM] S'LY EDGE TAYLOR			[TO] N'LY EDGE WILSON		

Figure 35. PCI report.

REPORT DATE - 81/08/10.

MAINTENANCE AND REPAIR GUIDELINES

BRANCH NAME - DICKMAN STREET
BRANCH NMBR - IDICK
SECTION NMBR - 01

SECTION LENGTH - 414 LF
SECTION WIDTH - 21 LF
SECTION AREA - 966 SY

INSPECTION DATE - 12/03/79

SECTION PCI - 53

DISTRESS TYPE	DIS SEV	DIST-QTY WORK-QTY	WORK TYPE	MATL CODE	LABOR HOURS	LABOR COSTS	MAT'L COSTS	EQUIP COSTS	TOTAL COSTS
ALLIGATOR CR	L	680 SF							
		680 SF	SEAL COATING	155	0.0	0	0	0	67
ALLIGATOR CR	M	60 SF							
		60 SF	SHALLOW PATCH	120	0.0	0	0	0	468
ALLIGATOR CR	H	15 SF							
		15 SF	DEEP PATCH	120	0.0	0	0	0	167
BLEEDING	L	8 LF							
			--- NO MAINTENANCE POLICY AVAILABLE ---						
DEPRESSION	L	18 SF							
			--- NO MAINTENANCE POLICY AVAILABLE ---						
EDGE CR	H	4 LF							
		6 SF	SHALLOW PATCH	120	0.0	0	0	0	43
LONG/TRANS CR	L	287 LF							
			--- NO MAINTENANCE POLICY AVAILABLE ---						
PATCH/UTIL CUT	L	100 SF							
			--- NO MAINTENANCE POLICY AVAILABLE ---						
PATCH/UTIL CUT	M	50 SF							
		50 LF	CRACK FILLING	171	0.0	0	0	0	32
POTHOLE	H	4 NMBR							
		4 EA	DEEP PATCH	120	0.0	0	0	0	80
RUTTING	L	10 SF							
			--- NO MAINTENANCE POLICY AVAILABLE ---						
				TOTAL	0.0	0	0	0	857

* REPORT COMPLETE
C>-

Figure 36. Example of M&R requirements report.

COMPARISON OF M&R ALTERNATIVES
CENTERAL AVE
SECTION 01

INFLATION RATE 6.00 PERCENT
ANALYSIS PERIOD - 20 YEARS INTEREST RATE 10.00 PERCENT

ALTERNATIVE	DESCRIPTION	NET PRESENT COST
B	PATCH JOINTS AND OVERLAY WITH 2 IN AC	28858.
A	CONTINUE JOINT PATCHING AND SLAB REPLACEMENT	36842.
C	RECONSTRUCT WITH CONCRETE	50642.

DETAILED COMPARISON OF M&R ALTERNATIVES

	ALT A		ALT B		ALT C	
		PRES		PRES		PRES
YEAR	COST	COST	COST	COST	COST	COST
0 (FY80)	14410	14410	20410	20410	46000	46000
1 (FY81)	0	0	0	0	0	0
2 (FY82)	0	0	0	0	0	0
3 (FY83)	0	0	0	0	0	0
4 (FY84)	0	0	0	0	0	0
5 (FY85)	7610	6323	1000	830	0	0
6 (FY86)	0	0	0	0	0	0
7 (FY87)	0	0	0	0	0	0
8 (FY88)	0	0	0	0	0	0
9 (FY89)	0	0	0	0	0	0
10 (FY90)	7610	5254	1500	1035	1200	828
11 (FY91)	0	0	0	0	0	0
12 (FY92)	0	0	0	0	0	0
13 (FY93)	0	0	0	0	0	0
14 (FY94)	0	0	0	0	0	0
15 (FY95)	7610	4365	1500	860	0	0
16 (FY96)	0	0	0	0	0	0
17 (FY97)	0	0	0	0	0	0
18 (FY98)	0	0	0	0	0	0
19 (FY99)	0	0	0	0	0	0
20 (FY00)	13610	6488	12000	5720	8000	3813
TOTAL	50850	36841	36410	28857	55200	50642
SALVAGE	0	0	0	0	0	0
PRES WORTH		36841		28857		50642

Figure 37. Example of economic analysis report.

```
                        PCI FREQUENCY REPORT
INSTALLATION NAME: FORT EUSTIS                    REPORT DATE:  81/09/24.

BRANCH USE: ROADWAY
PAVEMENT RANK: P S T
SURFACE TYPE: AC  PCC
FAMILY HOUSING: B
                        TABLE OF PCI FREQUENCIES
                              YR= 1981/08
     CONDITION     PCI RANGE   NO OF SECTIONS    % OF SECTIONS
     FAILED         0 -  10          3               1.61
     V.POOR        11 -  25          0               0.00
     POOR          26 -  40          4               2.15
     FAIR          41 -  55         16               8.60
     GOOD          56 -  70         39              20.97
     V.GOOD        71 -  85         75              40.32
     EXCEL         86 - 100         49              26.34

   TOTAL NO. OF SECTION:    186
   AVERAGE PCI:              74
   NO. OF MISSING VALUE:      3
```

```
                        PCI FREQUENCY REPORT
INSTALLATION NAME: FORT EUSTIS                    REPORT DATE:  81/09/24.

BRANCH USE: ROADWAY
PAVEMENT RANK: P S T
SURFACE TYPE: AC  PCC
FAMILY HOUSING: B

                              YR= 1981/08


 NO.
SEC.        CONDITION
                          !
                          !
   3   1.61% FAILED       !**
                          !
   0   0.00% V.POOR       !
                          !
   4   2.15% POOR         !**
                          !
  16   8.60% FAIR         !************
                          !
  39  20.97% GOOD         !*****************************
                          !
  75  40.32% V.GOOD       !*********************************************************
                          !
  49  26.34% EXCEL        !*************************************
                          !
                          !
 ----                     !-------------!-------------!-------------!-------------!
  186                     0             19            38            57            76

                                            NO. OF SECTIONS


   TOTAL NO. OF SECTION:    186
   AVERAGE PCI:              74
   NO. OF MISSING VALUE:      3
```

Figure 38. Projected pavement condition distribution report.

Work requirements are determined as shown in Figure 22. However, PAVER can expedite this process considerably. For those sections where existing maintenance policy is to continue (usually the majority of sections in a pavement network), work requirements can be developed by PAVER automatically based on user maintenance policy and distress results of pavement inspections. For pavement sections where economic analysis is desirable to compare several M&R alternatives, PAVER can be used to perform the computations.

Incorporation of Improvements

It should be noted that PAVER has been designed so new technological procedures/improvements can be incorporated into it as they become available.

8 SUMMARY AND RECOMMENDATIONS

This report has presented a pavement maintenance management system (PAVER) for military installations. The system includes procedures for dividing pavement networks into manageable sections, pavement condition survey and rating, pavement evaluation, rational determination of maintenance and repair (M&R) needs and priorities, performing life cycle costing (LCC) on feasible M&R alternatives, and both manual and automated systems for data storage and retrieval.

The pavement condition rating procedure presented is based on the Pavement Condition Index (PCI). The PCI (Chapter 3) has been field validated and proven to be very useful in establishing M&R priorities and justification of pavement M&R projects (Chapter 4). The automated data storage and retrieval system (Chapter 7) was also designed to perform computations such as LCC and PCI. The system also provides custom designed reports based on data stored and/or processed.

The implementation of the pavement maintenance management system by military installations is highly recommended. The level of implementation is a function of the installation size, existing pavement condition, and available manpower and money resources. The highest level of implementation would be the inclusion of all pavements on the installation and use of the automated system. The lowest level would be use of the PCI and the guidelines presented in Chapter 4 as the basis for project approvals and establishment of priorities.

A gradual implementation may be practical for many installations. This includes starting with a specific group of pavements in the installation (such as primary roads and pavements experiencing a high rate of deterioration or requiring immediate attention) and then including other pavements on a predefined schedule.

CITED REFERENCES

Airfield Pavement Evaluation Program, Air Force Regulation 93-5 (Department of the Air Force [DAF], 1981).

Flexible Airfield Pavement Evaluation, Chapter 2, TM 5-827-2 (Department of the Army [DA], 1968), and AFM 88-24 (DAF, October 1968).

Flexible Pavements for Roads, Streets, Walks, and Open Storage Areas, Chapter 1, TM 5-822-5 (DA, 1977), and AFM 88-7 (DAF, April 1969).

Rigid Airfield Pavement Evaluation, TM 5-827-3 (DA, 1959).

Rigid Pavements for Roads, Streets, Walks, and Open Storage Areas, TM 5-822-6 (DA, 1977).

UNCITED REFERENCE

Maintenance and Repair of Surface Areas, TM 5-624 (DA, March 1977).

APPENDIX A:
DISTRESS IDENTIFICATION GUIDE

Distress Type–Asphalt	Page
Alligator Cracking	84
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User Instructions

Types of distress found in jointed concrete- and asphalt-surfaced pavements are listed alphabetically in this appendix. Each listing includes the name of the distress, its description, a narrative and photographic description of its severity levels, and its standard measurement or count criteria. Nineteen distress types have been identified for each of the asphalt- and jointed concrete-surfaced pavements; however, only some of these distress types will be encountered frequently during the inspection. Common distress types for asphalt-surfaced pavements include alligator cracking, block cracking, bumps, joint reflection cracking, longitudinal and transverse cracking, patching, potholes, rutting, and weathering. Common distress types for jointed concrete pavements include corner break, divided slab, joint seal damage, linear cracking, patching (more than 5 sq ft), scaling, shrinkage cracks, corner spalling, and joint spalling. The rest of the distress types included in this appendix may not be encountered as frequently, except in specific geographic locations. For example, durability ("D") cracking in concrete pavements may be encountered frequently in pavements subjected to a high number of freeze-thaw cycles.

It is important that the pavement inspector be thoroughly familiar with all common distress types and their levels of severity. When determining the PCI (see Figure 1)* for a pavement section, it is imperative that the inspector follow the definitions and criteria described in this manual and appendix. The inspector should study this appendix before an inspection and carry a copy for reference during the inspection.

Distress in Asphalt Pavements

During the field condition surveys and validation of the PCI, several questions were commonly asked regarding the identification and measurement of some of the distresses. The answers to these questions are included under the section titled "How to Measure" for each distress. For convenience, however, items that are frequently referenced are listed below:

1. If alligator cracking and rutting occur in the same area, each is recorded separately at its respective severity level.

2. If bleeding is counted, polished aggregate is not counted in the same area.

3. Bumps and sags are measured in units of linear feet.

4. If a crack occurs at the ridge or edge of a bump, the crack and bump are recorded separately.

5. If any distress (including cracking and potholes) is found in a patched area, it is not recorded; its effect on the patch, however, is considered in determining the security level of the patch.

6. A significant amount of polished aggregate should be present before it is counted.

7. Potholes are measured by the number of holes having a certain diameter, not in units of square feet.

The above is not intended to be a complete list. To properly measure each distress type, the inspector must be familiar with its individual measurement criteria.

Nineteen distress types for asphalt-surfaced pavement are listed alphabetically on pp 84 through 134 following the end of this introductory section.

Ride Quality

Ride quality must be evaluated in order to establish a severity level for the following distress types

1. Bumps

2. Corrugation

3. Railroad crossings

4. Shoving

5. Swells

To determine the effects these distresses have on ride quality, the inspector should use the following severity-level definitions of ride quality:

1. L (low). Vehicle vibrations (e.g., from corrugation) are noticeable, but no reduction in speed is necessary for comfort or safety, and/or individual bumps or settlements cause the vehicle to bounce slightly, but create little discomfort.

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*Figures in this appendix are numbered in arabic numerals and should not be confused with figures of the same number in the main text.

2. M (medium). Vehicle vibrations are significant and some reduction in speed is necessary for safety and comfort, and/or individual bumps or settlements cause the vehicle to bounce significantly, creating some discomfort.

3. H (high). Vehicle vibrations are so excessive that speed must be reduced considerably for safety and comfort, and/or individual bumps or settlements cause the vehicle to bounce excessively, creating substantial discomfort, and/or a safety hazard, and/or high potential vehicle damage.

Ride quality is determined by riding in a standard-size automobile over the pavement section at the posted speed limit. Pavement sections near stop signs should be rated at the normal deceleration speed used when approaching the sign.

ALPHABETICAL LISTING OF DISTRESS TYPES

DISTRESS TYPE–ASPHALT

Name of Distress: Alligator Cracking

Description: Alligator or fatigue cracking is a series of interconnecting cracks caused by fatigue failure of the asphalt concrete surface under repeated traffic loading. Cracking begins at the bottom of the asphalt surface (or stabilized base) where tensile stress and strain are highest under a wheel load. The cracks propagate to the surface initially as a series of parallel longitudinal cracks. After repeated traffic loading, the cracks connect, forming many-sided, sharp-angled pieces that develop a pattern resembling chicken wire or the skin of an alligator. The pieces are less than 2 ft (.6 m) on the longest side.

Alligator cracking occurs only in areas subjected to repeated traffic loading, such as wheel paths. Therefore, it would not occur over an entire area unless the entire area were subjected to traffic loading. (Pattern-type cracking which occurs over an entire area that is not subjected to loading is called block cracking, which is not a load-associated distress.)

Alligator cracking is considered a major structural distress and is usually accompanied by rutting.

Severity Levels:

L – Fine, longitudinal hairline cracks running parallel to each other with none or only a few interconnecting cracks. The cracks are not spalled.* (Figures 2 and 3)

M – Further development of light alligator cracks into a pattern or network of cracks that may be lightly spalled. (Figures 4, 5, and 6)

H – Network or pattern cracking has progressed so that the pieces are well defined and spalled at the edges. Some of the pieces may rock under traffic. (Figures 7 and 8)

How to Measure: Alligator cracking is measured in square feet of surface area. The major difficulty in measuring this type of distress is that two or three levels of severity often exist within one distressed area. If these portions can be easily distinguished from each other, they should be measured and recorded separately. However, if the different levels of severity cannot be divided easily, the entire area should be rated at the highest severity level present.

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*Crack spalling is a breakdown of the material along the sides of the crack.

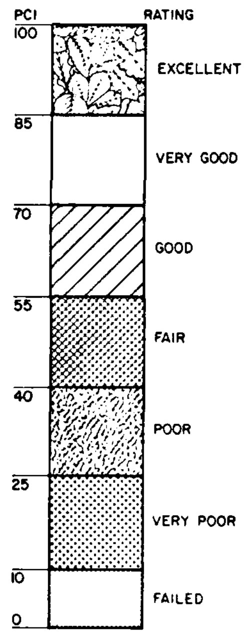

Figure 1. Pavement Condition Index.

Figure 2. Low-severity alligator cracking.

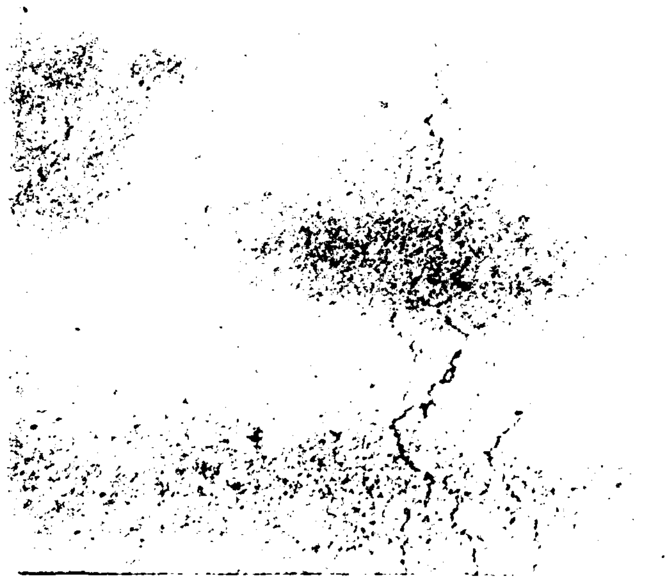

Figure 3. Low-severity alligator cracking.

Figure 4. Medium-severity alligator cracking.

Figure 5. Medium-severity alligator cracking.

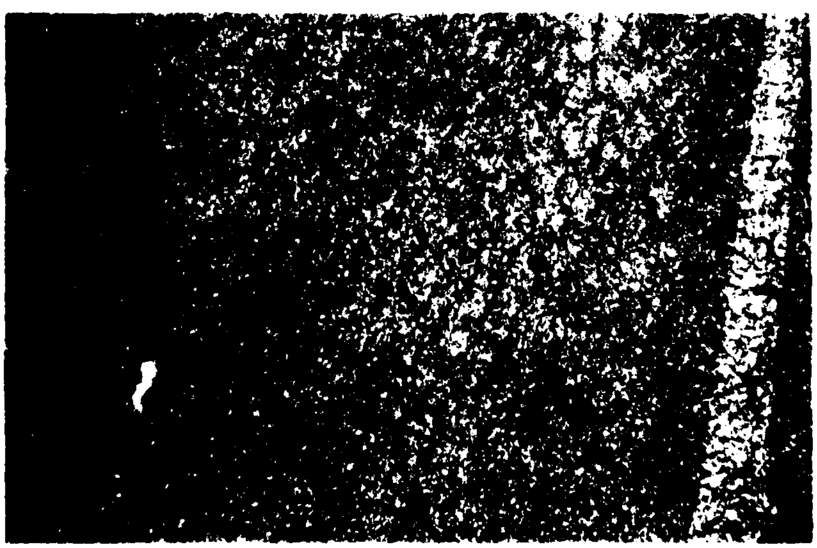

Figure 6. Medium-severity alligator cracking.

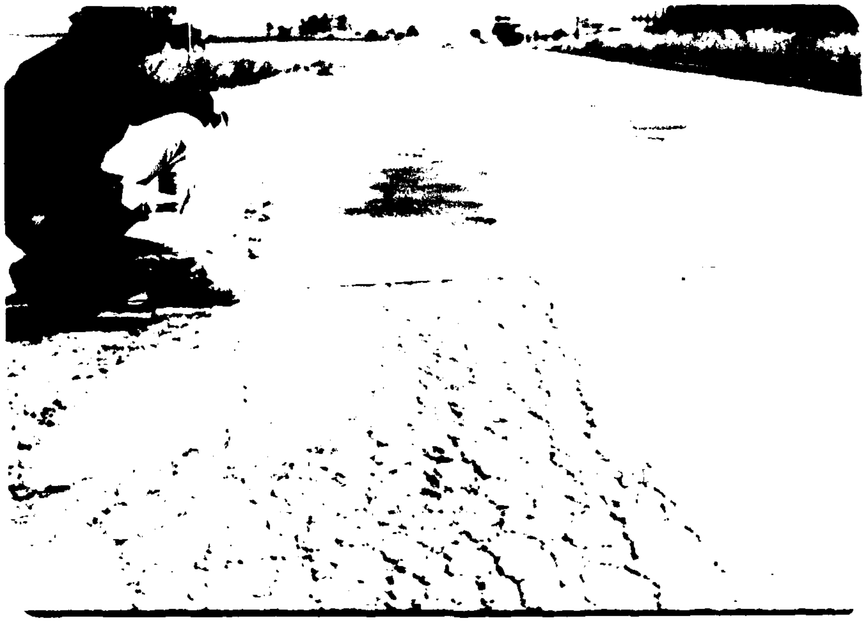

Figure 7. High-severity alligator cracking.

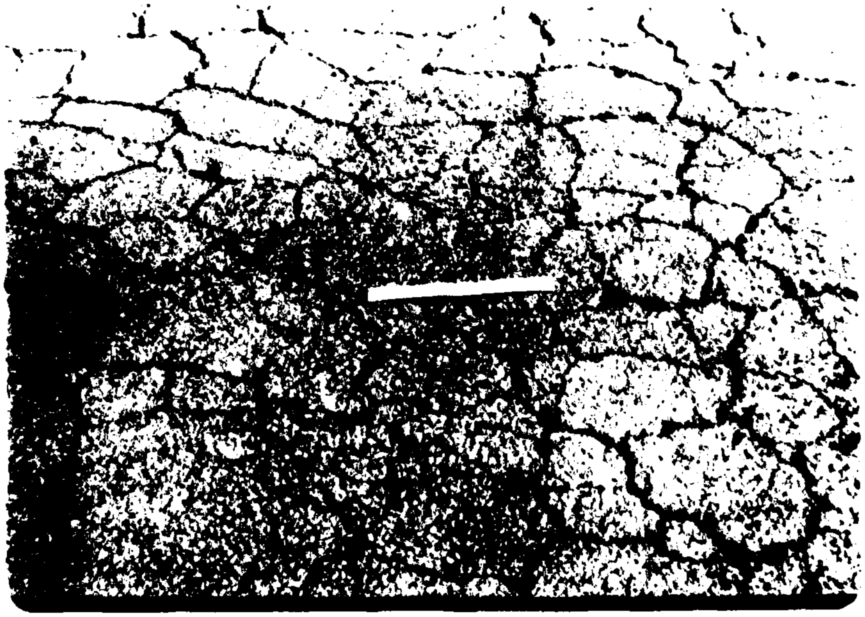

Figure 8. High-severity alligator cracking.

Name of Distress: Bleeding

Description: Bleeding is a film of bituminous material on the pavement surface which creates a shiny, glasslike, reflecting surface that usually becomes quite sticky. Bleeding is caused by excessive asphalt cement or tars in the mix, excess application of a bituminous sealant, and/or low air void content. It occurs when asphalt fills the voids of the mix during hot weather and then expands onto the pavement surface. Since the bleeding process is not reversible during cold weather, asphalt or tar will accumulate on the surface.

Severity Levels:

L – Bleeding has only occurred to a very slight degree and it is noticeable only during a few days of the year. Asphalt does not stick to shoes or vehicles. (Figure 9)

M – Bleeding has occurred to the extent that asphalt sticks to shoes and vehicles during only a few weeks of the year. (Figure 10)

H – Bleeding has occurred extensively and considerable asphalt sticks to shoes and vehicles during at least several weeks of the year. (Figure 11)

How to Measure: Bleeding is measured in square feet of surface area.

If bleeding is counted, polished aggregate should not be counted.

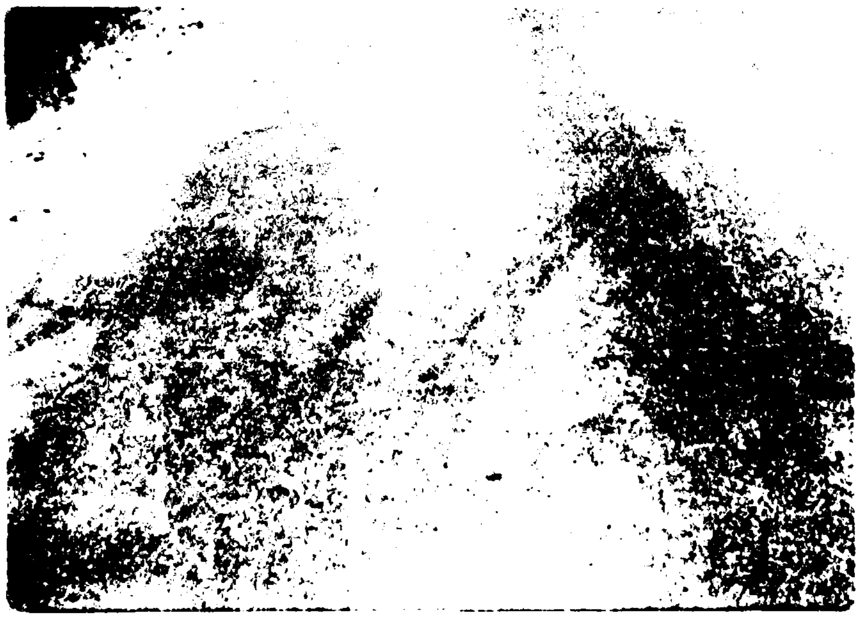

Figure 9. Low-severity bleeding.

Figure 10. Medium-severity bleeding.

Figure 11. High-severity bleeding.

Name of Distress: Block Cracking

Description: Block cracks are interconnected cracks that divide the pavement into approximately rectangular pieces. The blocks may range in size from approximately 1 by 1 ft (.3 by .3 m) to 10 by 10 ft (3 by 3 m). Block cracking is caused mainly by shrinkage of the asphalt concrete and daily temperature cycling (which results in daily stress/strain cycling). It is not load-associated. Block cracking usually indicates that the asphalt has hardened significantly. Block cracking normally occurs over a large proportion of pavement area, but sometimes will occur only in nontraffic areas. This type of distress differs from alligator cracking in that alligator cracks form smaller, many-sided pieces with sharp angles. Also, unlike block cracks, alligator cracks are caused by repeated traffic loadings, and are therefore found only in traffic areas (i.e., wheel paths).

Severity Levels:

L – Blocks are defined by low* severity cracks. (Figure 12)

M – Blocks are defined by medium* severity cracks. (Figures 13 and 14)

H – Blocks are defined by high* severity cracks. (Figure 15)

How to Measure: Block cracking is measured in square feet of surface area. It usually occurs at one severity level in a given pattern section; however, any areas of the pavement section having distinctly different levels of severity should be measured and recorded separately.

---

*See definition of longitudinal and transverse cracking, p 111.

Figure 12. Low-severity block cracking.

Figure 13. Medium-severity block cracking.

Figure 14. Medium-severity block cracking.

Figure 15. High-severity block cracking (a few inches around the crack are severely broken).

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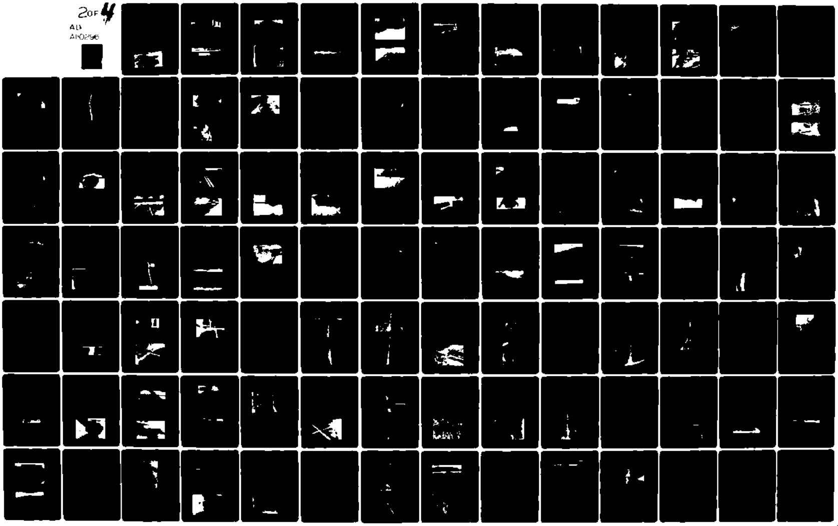

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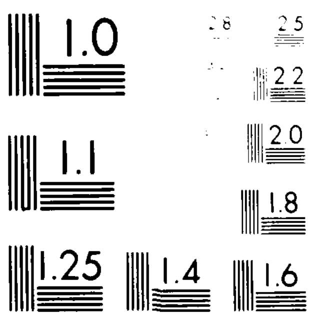

Name of Distress: Bumps and Sags

Description: Bumps are small, localized, upward displacements of the pavement surface. They are different from shoves in that shoves are caused by unstable pavement. Bumps, on the other hand, can be caused by several factors, including:

1. Buckling or bulging of underlying portland cement concrete (PCC) slabs in asphalt concrete [AC] overlayover PCC pavement.

2. Frost heave (ice, lens growth).

3. Infiltration and buildup of material in a crack in combination with traffic loading (sometimes called tenting).

Sags are small, abrupt, downward displacements of the pavement surface.

Distortion and displacement which occurs over large areas of the pavement surface, causing large and/or long dips in the pavement is called swelling (see p 131).

Severity Levels:

L -- Bump or sag causes low-severity ride quality. (Figure 16)

M -- Bump or sag causes medium-severity ride quality. (Figures 17, 18, and 19)

H -- Bump or sag causes high-severity ride quality. (Figure 20)

How to Measure: Bumps or sags are measured in linear feet. If bumps appear in a pattern perpendicular to traffic flow and are spaced at less than 10 ft (3 m), the distress is called corrugation. If the bump occurs in combination with a crack, the crack is also recorded.

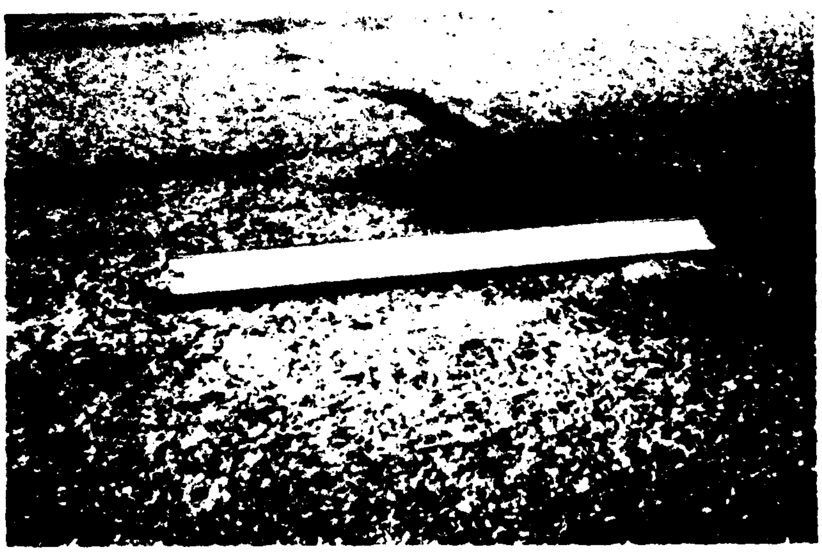

Figure 16. Low-severity bumps and sags.

Figure 17. Medium-severity bumps and sags.

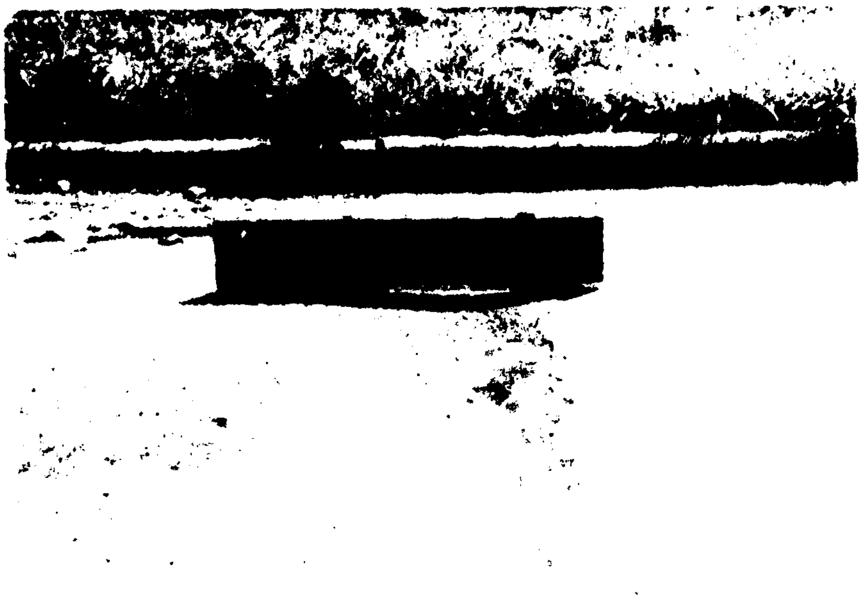

Figure 18. Medium-severity bumps and sags.

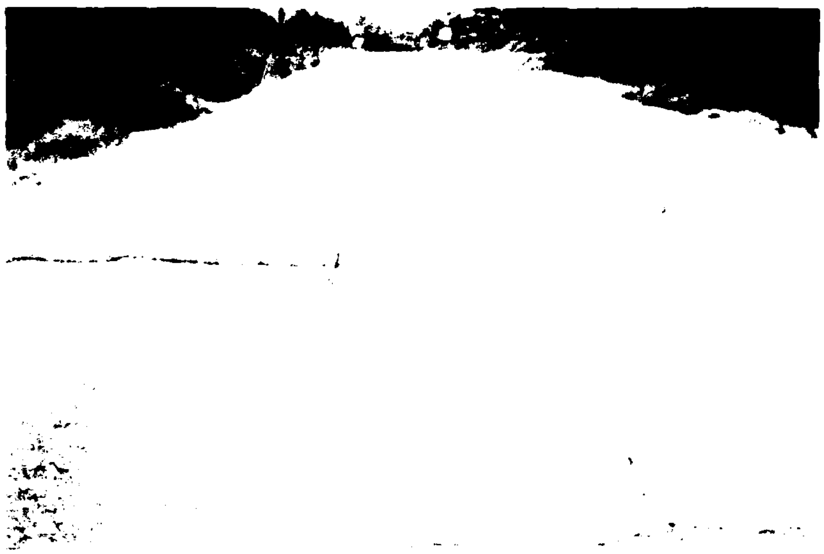

Figure 19. Medium-severity bumps and sags.

Figure 20. High-severity bumps and sags.

Name of Distress: Corrugation

Description: Corrugation (also known as washboarding) is a series of closely spaced ridges and valleys (ripples) occurring at fairly regular intervals usually less than 10 ft (3 m) along the pavement. The ridges are perpendicular to the traffic direction. This type of distress is usually caused by traffic action combined with an unstable pavement surface or base. If bumps occur in a series of less than 10 ft (3 m), due to any cause, the distress is considered corrugation.

Severity Levels:

L – Corrugation produces low-severity ride quality. (Figure 21)

M Corrugation produces medium-severity ride quality. (Figures 22 and 23)

H – Corrugation produces high-severity ride quality. (Figure 24)

How to Measure: Corrugation is measured in square feet of surface area.

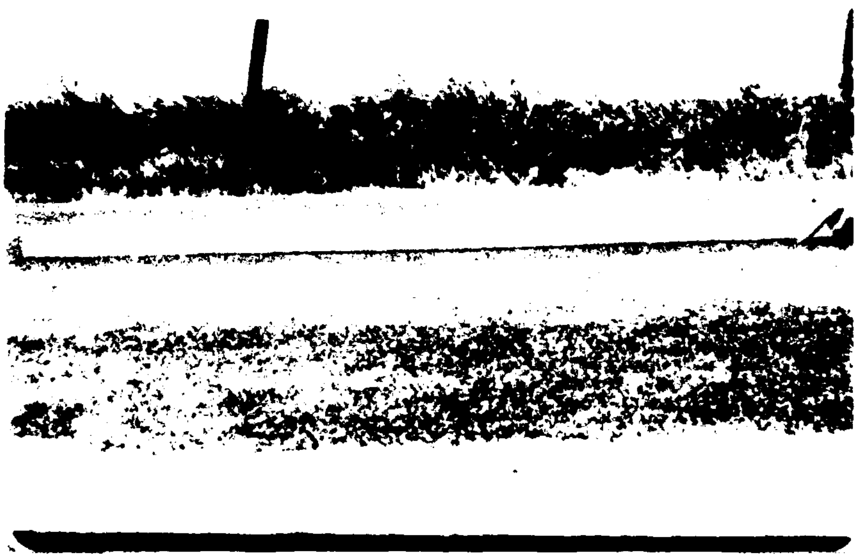

Figure 21. Low-severity corrugation.

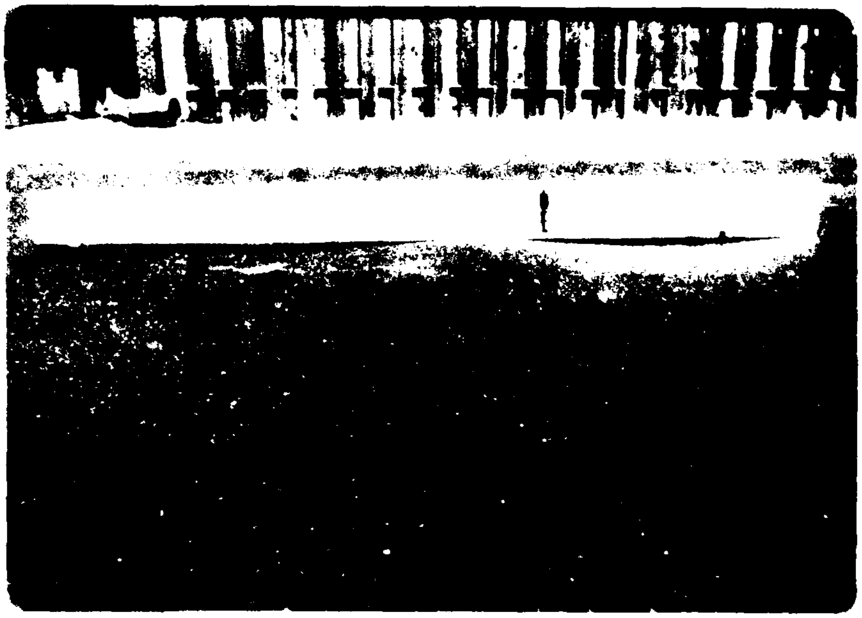

Figure 22. Medium-severity corrugation

Figure 23. Medium-severity corrugation.

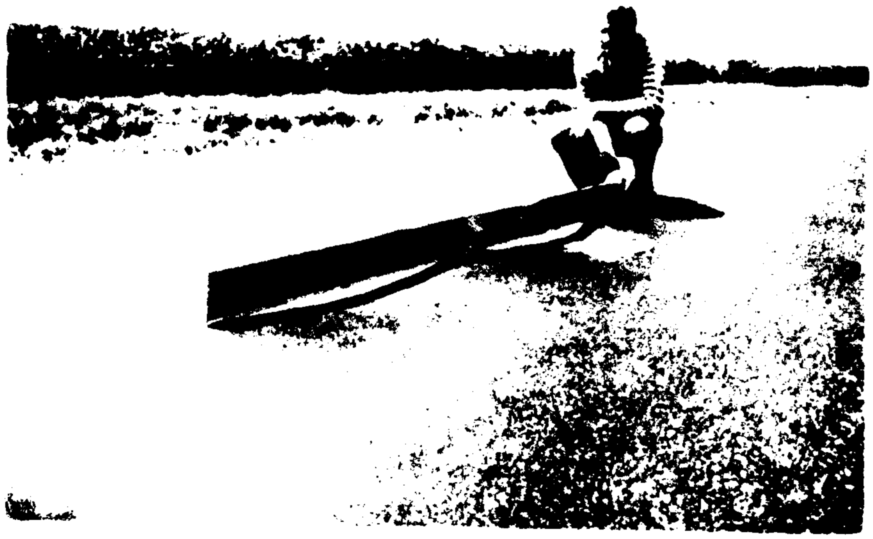

Figure 24. High-severity corrugation.

Name of Distress: Depression

Description: Localized pavement surface areas with elevations slightly lower than those of the surrounding pavement are called depressions. In many instances, light depressions are not noticeable until after a rain, when ponding water creates "birdbath" areas; on dry pavement, depressions can be spotted by looking for stains caused by ponding water. Depressions are created by settlement of the foundation soil or are a result of improper construction. Depressions cause some roughness, and when filled with water of sufficient depth, can cause hydroplaning.

Sags, unlike depressions, are abrupt drops in elevations (see p 94).

Severity Levels: Maximum Depth of Depression

L – 1/2 to 1 in. (13 to 25 mm)

M – 1 to 2 in. (25 to 51 mm)

H – more than 2 in. (51 mm)

See Figures 25 through 27.

How to Measure: Depressions are measured in square feet of surface area.

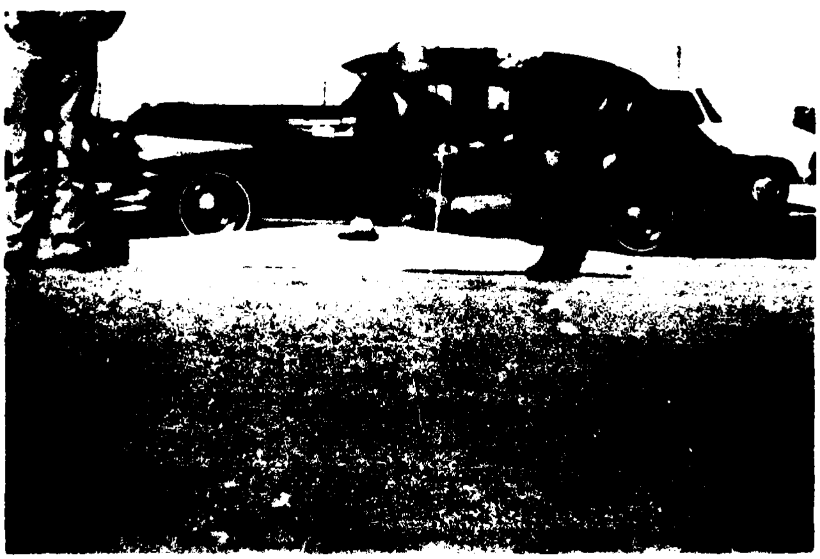

Figure 25. Low-severity depression.

Figure 26. Medium-severity depression.

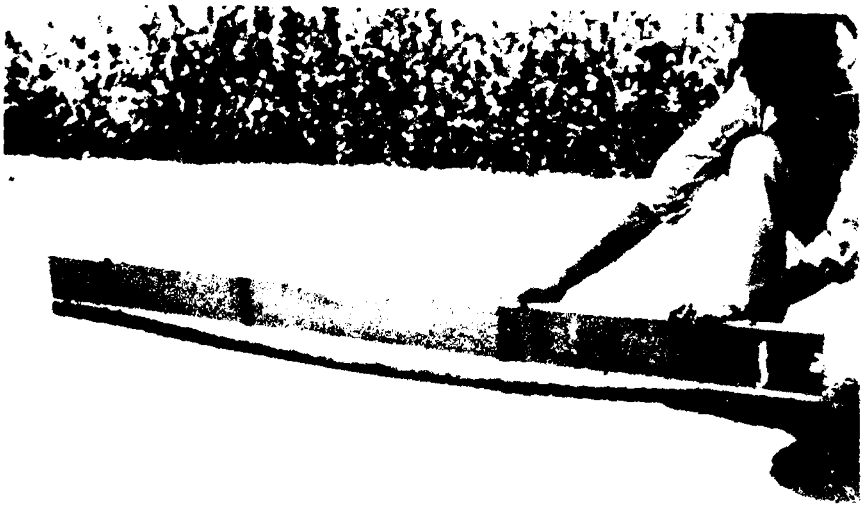

Figure 27. High-severity depression.

Name of Distress: Edge Cracking

Description: Edge cracks are parallel to and usually within 1 to 2 ft (.3 to .6 m) of the outer edge of the pavement. This distress is accelerated by traffic loading and can be caused by frost-weakened base or subgrade near the edge of the pavement. The area between the crack and pavement edge is classified as raveled if it breaks up (sometimes to the extent that pieces are removed).

Severity Levels:

L – Low or medium cracking with no breakup or raveling. (Figure 28)

M – Medium cracks with some breakup and raveling. (Figure 29)

H – Considerable breakup or raveling along the edge. (Figures 30 and 31)

How to Measure: Edge cracking is measured in linear feet.

Figure 28. Low-severity edge cracking.

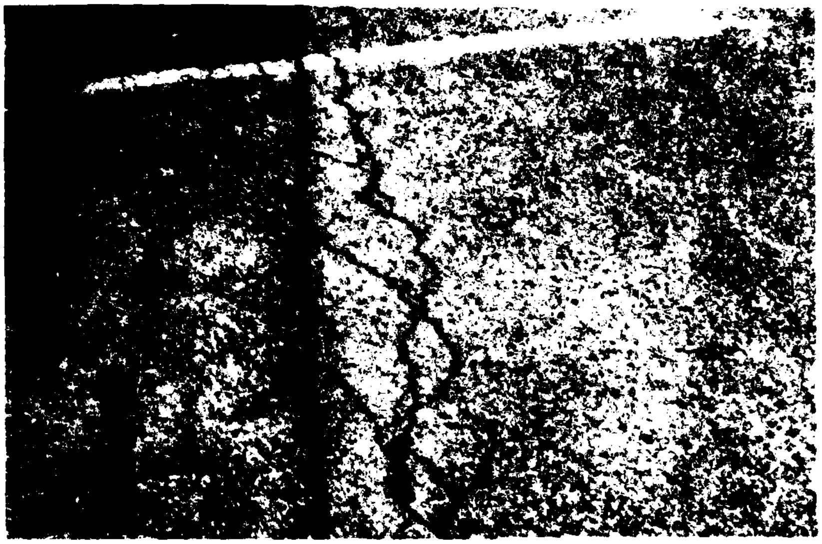

Figure 29. Medium-severity edge cracking.

Figure 30. High-severity edge cracking.

Figure 31. High-severity edge cracking.

Name of Distress: Joint Reflection Cracking (from Longitudinal and Transverse PCC Slabs)

Description: This distress occurs only on asphalt-surfaced pavements which have been laid over a PCC slab. It does not include reflection cracks from any other type of base (i.e., cement- or lime-stabilized); such cracks are listed as longitudinal cracks and transverse cracks. Joint reflection cracks are mainly caused by the thermal- or moisture-induced movement of the PCC slab beneath the AC surface. This distress is not load-related; however, traffic loading may cause a breakdown of the AC surface near the crack. If the pavement is fragmented along a crack, the crack is said to be spalled. A knowledge of slab dimensions beneath the AC surface will help to identify these distresses.

Severity Levels: L – One of the following conditions exist (Figure 32):

1. Nonfilled crack width is less than 3/8 in. (10 mm), or
2. Filled crack of any width (filler in satisfactory condition).

M – One of the following conditions exist (Figure 33):

1. Nonfilled crack width is 3/8 to 3 in. (10 to 76 mm).
2. Nonfilled crack of any width up to 3 in. (76 mm) surrounded by light random cracking. (Figure 33)
3. Filled crack of any width surrounded by light random cracking.

H – One of the following conditions exist (Figure 34):

1. Any crack filled or nonfilled surrounded by medium or high severity random cracking.
2. Nonfilled cracks over 3 in. (76 mm).
3. A crack of any width where a few inches of pavement around a crack is severely broken. (Crack is severely broken.)

How to Measure: Joint reflection cracking is measured in linear feet. The length and severity level of each crack should be recorded separately. For example, a crack that is 50 ft (15 m) long may have 10 ft (3 m) of high severity; these would all be recorded separately. If a bump occurs at the reflection crack, it is also recorded.

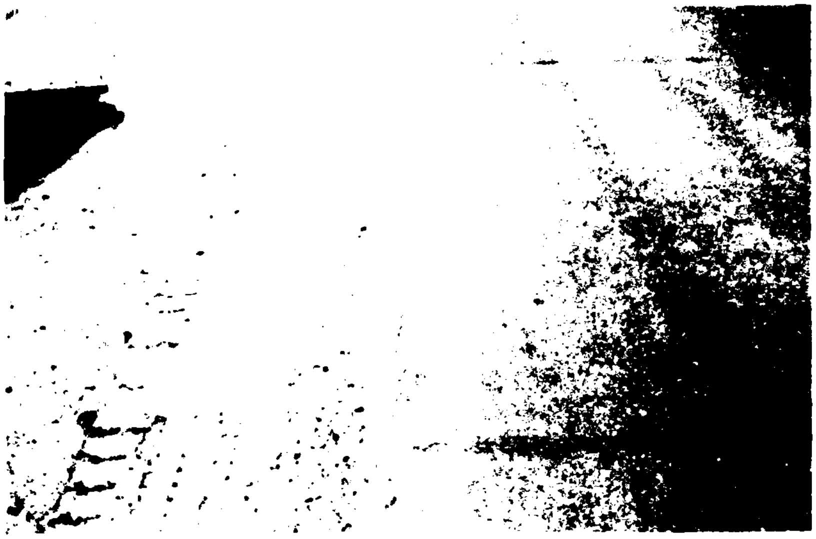

Figure 32. Low-severity joint reflection cracking.

Figure 33. Medium-severity joint reflection cracking.

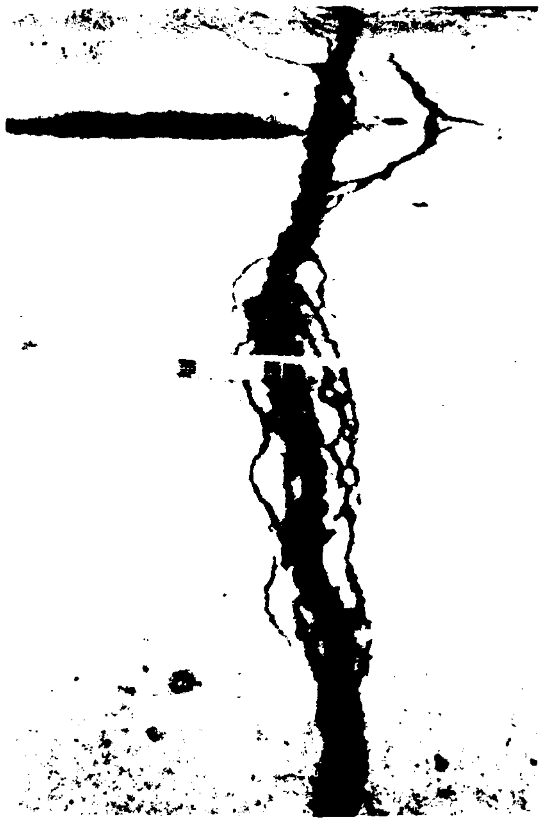

Figure 34. High-severity joint reflection cracking.

Name of Distress: Lane Shoulder Drop Off

Description: Lane shoulder drop off is a difference in elevation between the pavement edge and the shoulder. This distress is caused by shoulder erosion, shoulder settlement, or by building up the roadway without adjusting the shoulder level.

Severity Levels:

L The difference in elevation between the pavement edge and shoulder is 1 to 2 in. (25 to 51 mm). (Figure 35)

M The difference in elevation is over 2 to 4 in. (51 to 102 mm). (Figure 36)

H The difference in elevation is greater than 4 in. (102 mm). (Figures 37 and 38)

How to Measure: Lane/shoulder drop off is measured in linear feet.

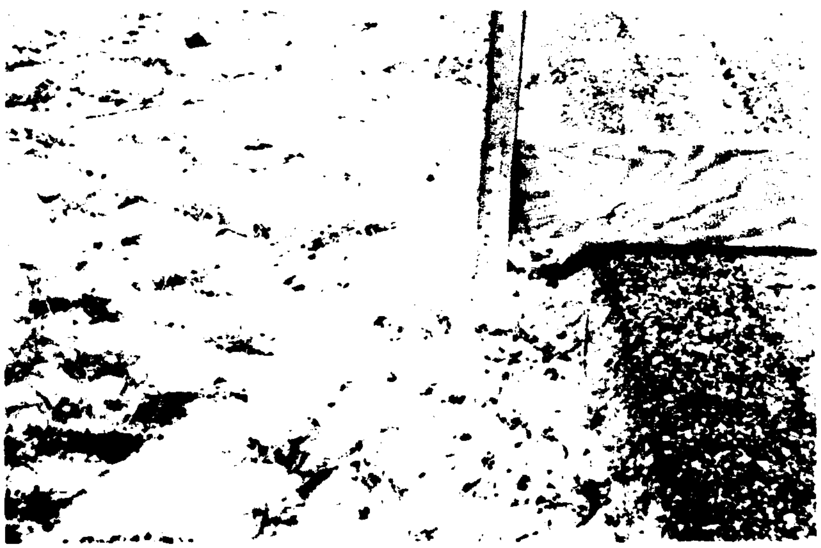

Figure 35. Low-severity lane/shoulder drop off.

Figure 36. Medium-severity lane/shoulder drop off.

Figure 37. High-severity lane/shoulder drop off.

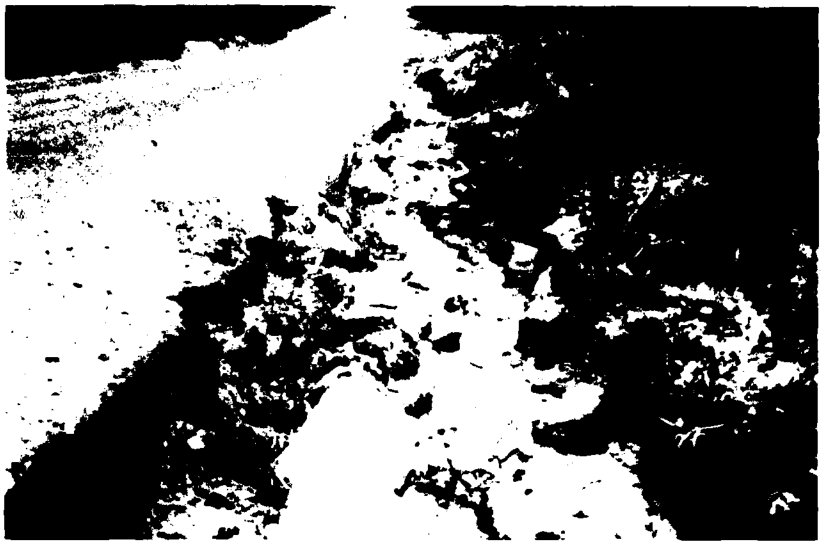

Figure 38. High-severity lane/shoulder drop off.

Name of Distress: Longitudinal and Transverse Cracking (Non-PCC Slab Joint Reflective)

Description: Longitudinal cracks are parallel to the pavement's centerline or laydown direction. They may be caused by:

1. A poorly constructed paving lane joint.

2. Shrinkage of the AC surface due to low temperatures or hardening of the asphalt and/or daily temperature cycling.

3. A reflective crack caused by cracking beneath the surface course, including cracks in PCC slabs (but not PCC joints).

Transverse cracks extend across the pavement at approximately right angles to the pavement centerline or direction of laydown. These may be caused by conditions (2) and (3) above. These types of cracks are not usually load-associated.

Severity Levels: L – One of the following conditions exist (see Figure 39):

1. Nonfilled crack width is less than 3/8 in. (10 mm), or

2. Filled crack of any width (filler in satisfactory condition).

M – One of the following conditions exist (Figures 40 and 41):

1. Nonfilled crack width is 3/8 to 3 in. (10 to 76 mm).

2. Nonfilled crack of any width up to 3 in. (76 mm) surrounded by light and random cracking.

3. Filled crack of any width surrounded by light random cracking.

H – One of the following conditions exist (Figure 42):

1. Any crack filled or nonfilled surrounded by medium or high severity random cracking.

2. Nonfilled crack over 3 in. (76 mm).

3. A crack of any width where a few inches of pavement around the crack is severely broken.

How to Measure: Longitudinal and transverse cracks are measured in linear feet. The length and severity of each crack should be recorded after identification. If the crack does not have the same severity level along its entire length, each portion of the crack having a different severity level should be recorded separately. If a bump or sag occurs at the crack, it is also recorded.

Figure 39. Low-severity longitudinal and transverse cracking.

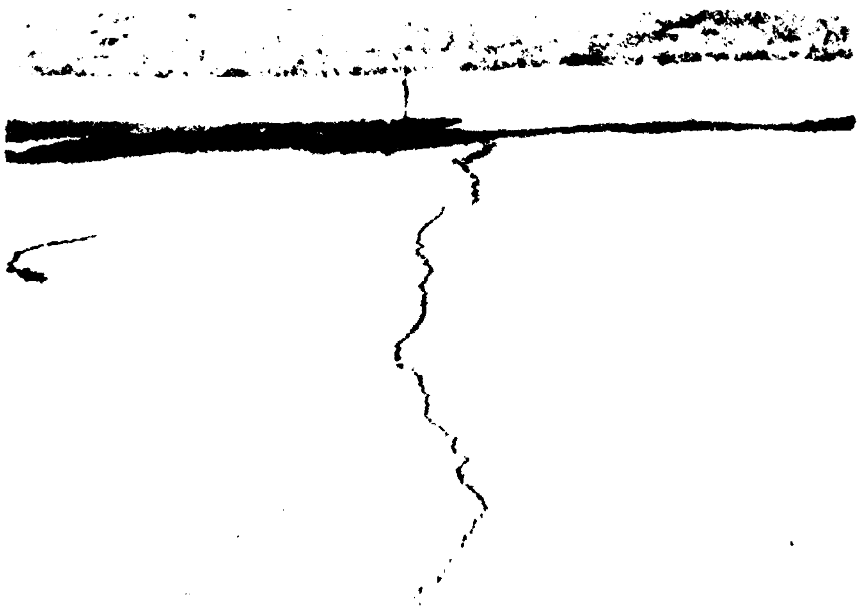

Figure 40. Medium-severity longitudinal and transverse cracking.

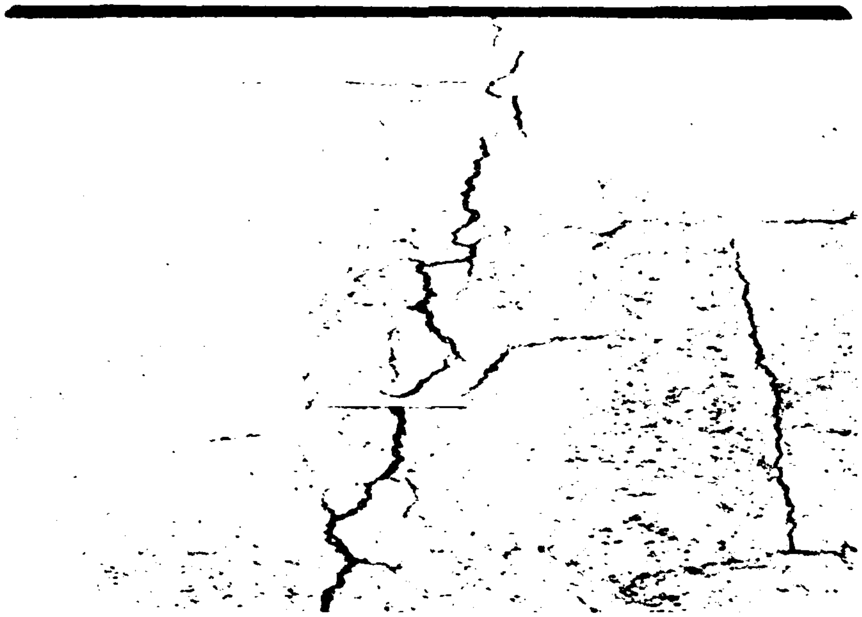

Figure 41. Medium-severity longitudinal and transverse cracking [3/4 in. (19 mm) crack surrounded by light random cracks].

Figure 42. High-severity longitudinal and transverse cracking.

Name of Distress: Patching and Utility Cut Patching

Description: A patch is an area of pavement which has been replaced with new material to repair the existing pavement.

A patch is considered a defect no matter how well it is performing (a patched area or adjacent area usually does not perform as well as an original pavement section). Generally, some roughness is associated with this distress.

Severity Levels:

L – Patch is in good condition and satisfactory. Ride quality is rated as low severity or better. (Figures 43, 44, and 45)

M – Patch is moderately deteriorated and/or ride quality is rated as medium severity. (Figure 46)

H – Patch is badly deteriorated and/or ride quality is rated as high severity. Patch needs replacement soon. (Figure 47)

How to Measure: Patching is rated in square feet of surface area. However, if a single patch has areas of differing severity, these areas should be measured and recorded separately. For example, a 25-sq-ft (2.32 m^2) patch may have 10 sq ft (.9 m^2) of medium severity and 15 sq ft (1.35 m^2) of low severity. These areas would be recorded separately. No other distresses (e.g., shoving or cracking) are recorded within a patch (e.g., even if patch material is shoving or cracking, the area is rated only as a patch).

If a large amount of pavement has been replaced, it should not be recorded as a patch, but considered as new pavement (e.g., replacement of full intersection).

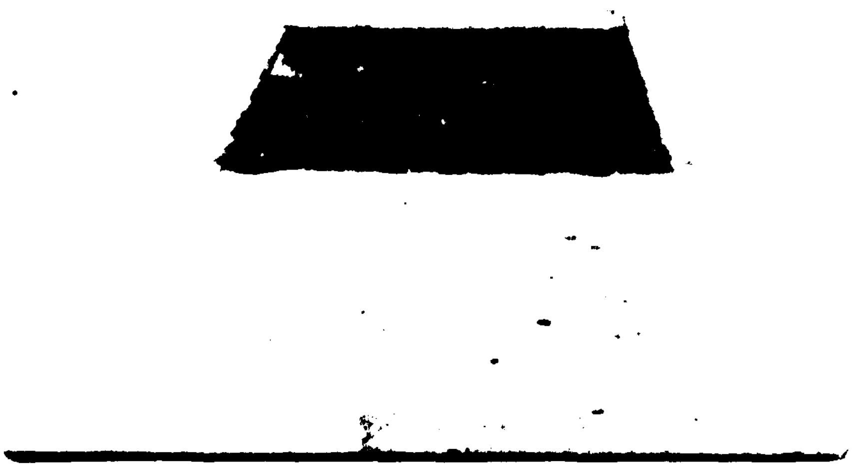

Figure 43. Low-severity patching and utility cut patching.

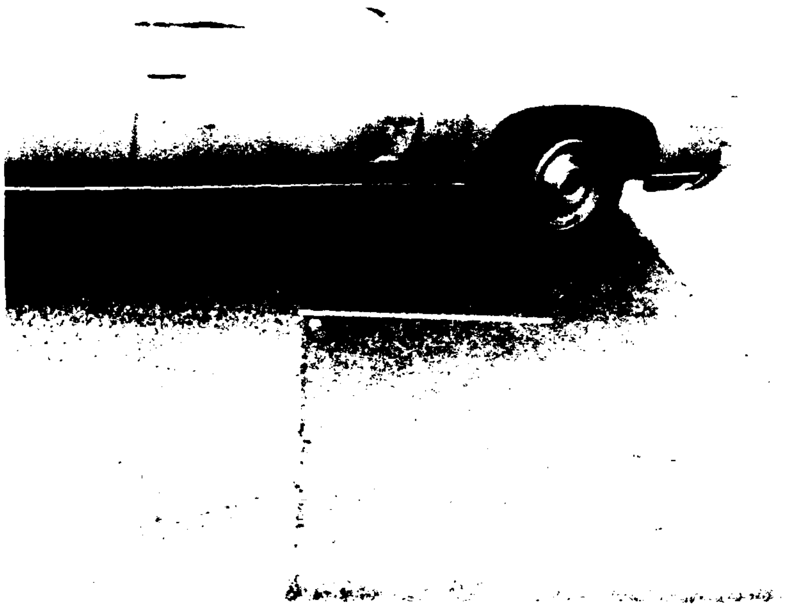

Figure 44. Low-severity patching and utility cut patching.

Figure 45. Low-severity patching and utility cut patching.

Figure 46. Medium-severity patch.

Figure 47. High-severity patching and utility cut patching.

Name of Distress: Polished Aggregate

Description: This distress is caused by repeated traffic applications. When the aggregate in the surface becomes smooth to the touch, adhesion with vehicle tires is considerably reduced. When the portion of aggregate extending above the surface is small, the pavement texture does not significantly contribute to reducing vehicle speed. Polished aggregate should be counted when close examinations reveals that the aggregate extending above the asphalt is negligible, and the surface aggregate is smooth to the touch. This type of distress is indicated when the number on a skid resistance test is low or has dropped significantly from previous ratings.

Severity Levels: No degrees of severity are defined. However, the degree of polishing should be significant before it is included in the condition survey and rated as a defect (Figure 48)

How to Count: Polished aggregate is measured in square feet of surface area. If bleeding is counted, polished aggregate should not be counted.

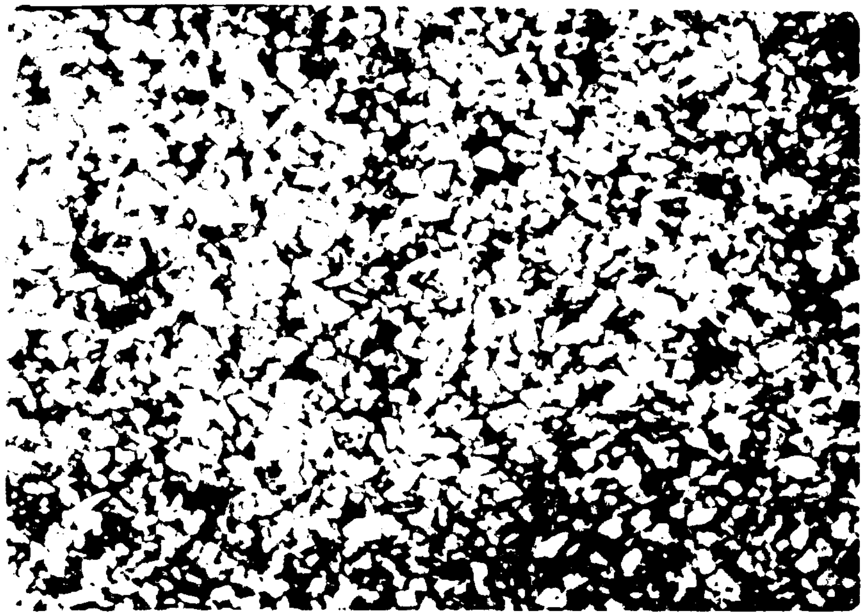

Figure 48. Polished aggregate.

Name of Distress: Potholes

Description: Potholes are small [usually less than 3 ft (.9 m) in diameter], bowl-shaped depressions in the pavement surface. They generally have sharp edges and vertical sides near the top of the hole. Their growth is accelerated by free moisture collection inside the hole. Potholes are produced when traffic abrades small pieces of the pavement surface. The pavement then continues to disintegrate because of poor surface mixtures, weak spots in the base or subgrade, or because it has reached a condition of high-severity alligator cracking. Potholes are generally structurally related distresses and should not be confused with raveling and weathering. Thus, when holes are created by high-severity alligator cracking, they should be identified as potholes, not as weathering.

Severity Levels: The levels of severity for potholes under 30 in. (762 mm) in diameter are based on both the diameter and the depth of the pothole according to the following table.

Maximum Depth of Pothole	Average Diameter (in.) (mm)		
	4 to 8 in. (102 to 203 mm)	> 8 to ≤ 18 in. (> 203 to ≤ 457 mm)	> 18 to ≤ 30 in. (> 457 to ≤ 762 mm)
1/2 to 1 in. *(1.27 to 2.54 cm)*	L	L	M
>1 to 2 in. (2.54 to 5.08 cm)	L	M	H
> 2 in. (5.08 cm)	M	M	H

If the pothole is over 30 in. (76 mm) in diameter, the area should be determined in square feet and divided by 5 sq ft (.47 m^2) to find the equivalent number of holes. If the depth is 1 in. (25 mm) or less, they are considered medium severity. If the depth is over 1 in. (25 mm), they are considered high severity. (Figures 49 through 53)

How to Measure: Potholes are measured by counting the number that are low, medium, and high severity and recording them separately.

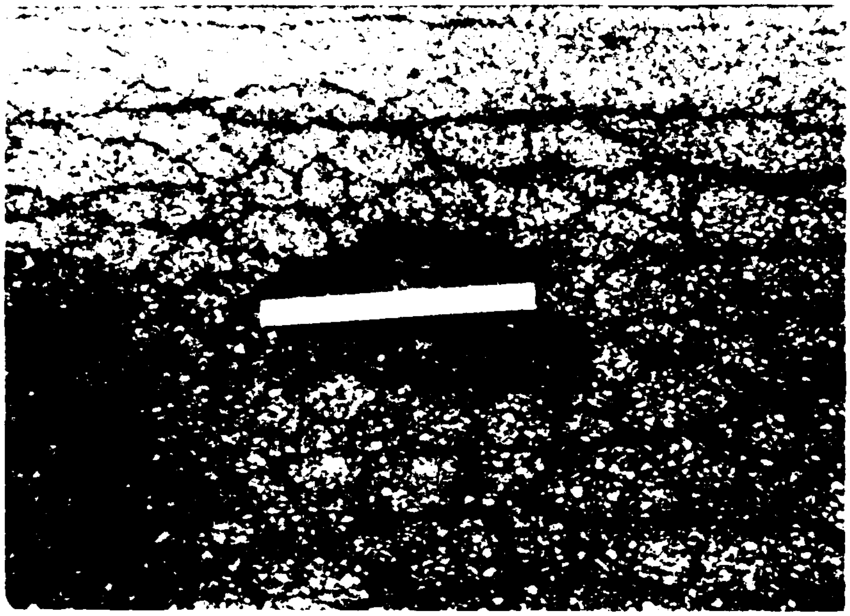

Figure 49. Low-severity pothole.

Figure 50. Low-severity pothole.

Figure 51. Medium-severity pothole.

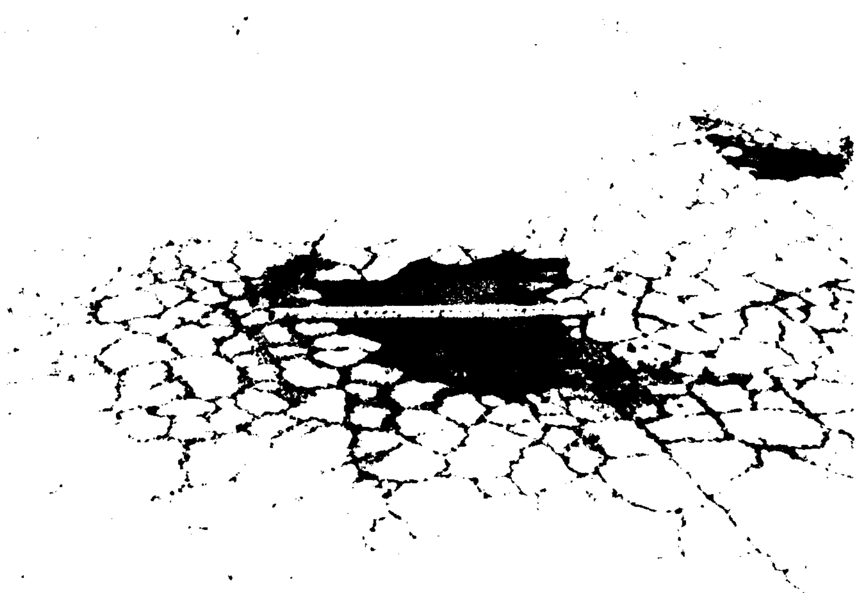

Figure 52. High-severity pothole.

Figure 53. High-severity pothole.

Name of Distress: Railroad Crossing

Description: Railroad crossing defects are depressions or bumps around and/or between tracks.

Severity Levels:

L - Railroad crossing causes low-severity ride quality. (Figure 54)

M - Railroad crossing causes medium-severity ride quality. (Figure 55)

H - Railroad crossing causes high-severity ride quality. (Figure 56)

How to Measure: The area of the crossing is measured in square feet of surface area. If the crossing does not affect ride quality, it should not be counted. Any large bump created by the tracks should be counted as part of the crossing.

Figure 54. Low-severity railroad crossing.

Figure 55. Medium-severity railroad crossing.

Figure 56. High-severity railroad crossing.

Name of Distress: Rutting

Description: A rut is a surface depression in the wheel paths. Pavement uplift may occur along the sides of the rut, but, in many instances, ruts are noticeable only after a rainfall, when the paths are filled with water. Rutting stems from a permanent deformation in any of the pavement layers or subgrade, usually caused by consolidated or lateral movement of the materials due to traffic loads. Significant rutting can lead to major structural failure of the pavement.

Severity Levels: *Mean Rut Depth*

L 1/4 to $\leq$ 1/2 in. (6 to $\leq$ 13 mm)

M $>$ 1/2 to $\leq$ 1 in. ($>$ 13 to $\leq$ 25 mm)

H $>$ 1 in. ($>$ 25 mm)

See Figures 57 through 60.

How to Measure: Rutting is measured in square feet of surface area, and its severity is determined by the mean depth of the rut (see above). The mean rut depth is calculated by laying a straight-edge across the rut, measuring its depth, then using measurements taken along the length of the rut to compute its mean depth in inches.

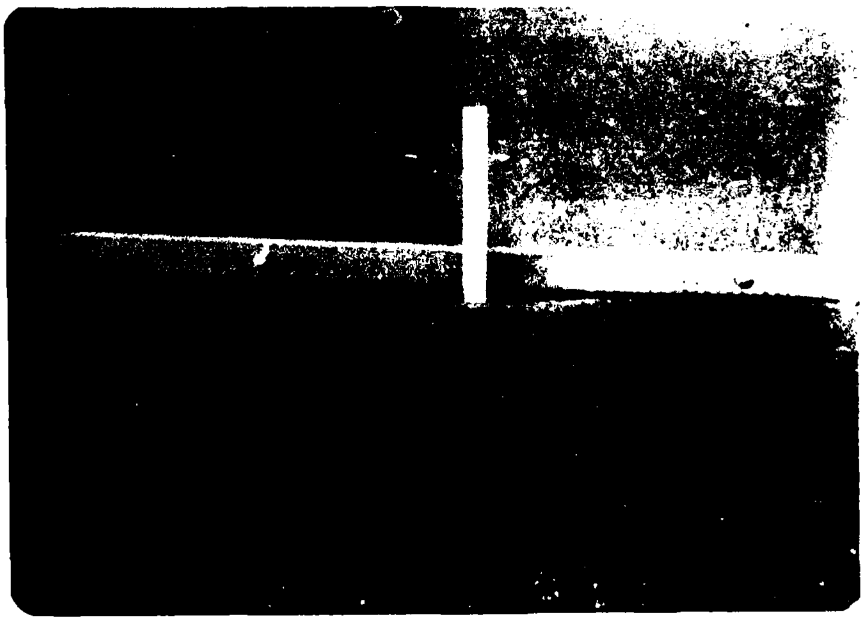

Figure 57. Low-severity rutting.

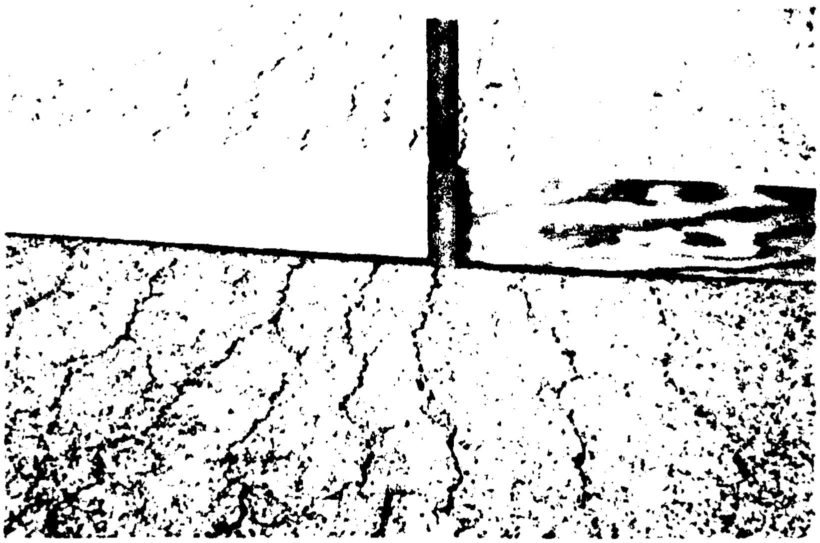

Figure 58. Low-severity rutting.

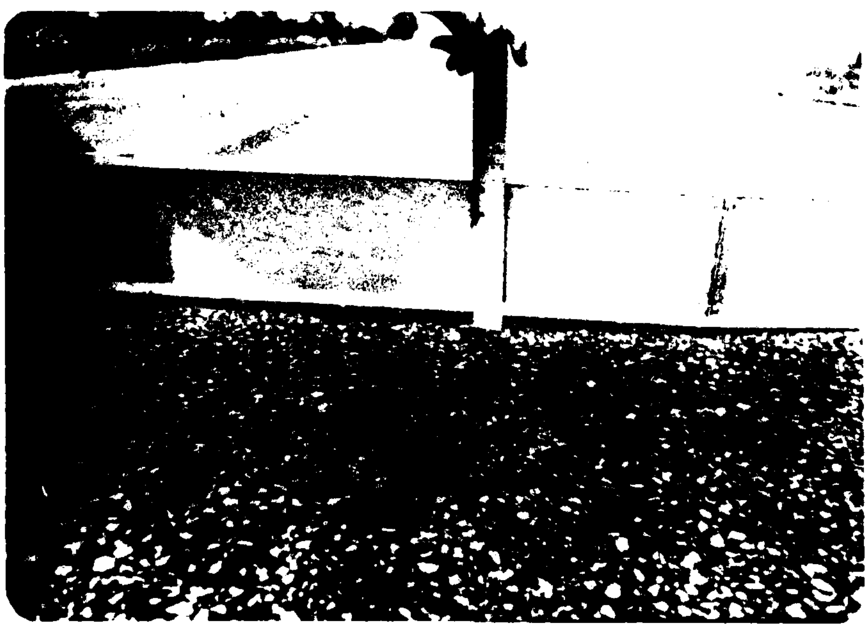

Figure 59. Medium-severity rutting.

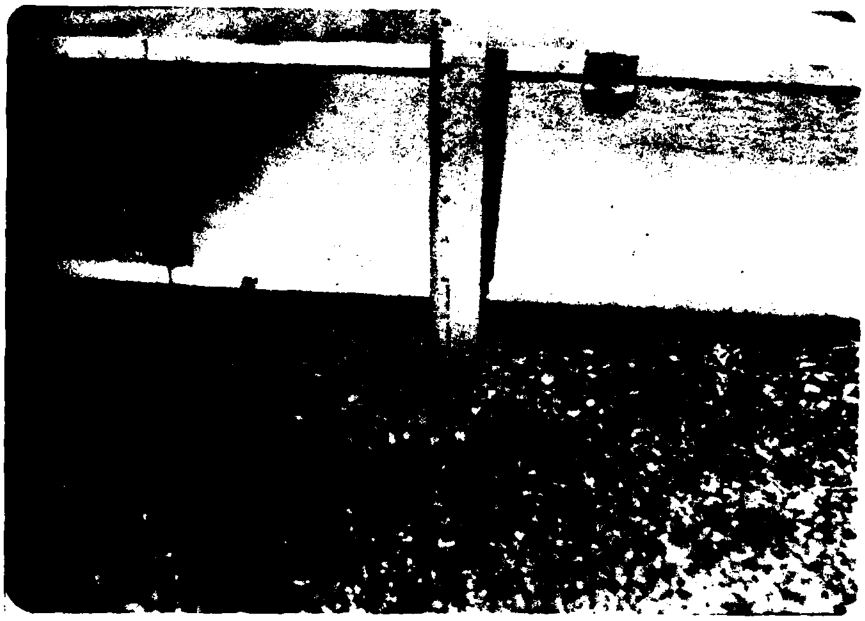

Figure 60. High-severity rutting.

Name of Distress: Shoving

Description: Shoving is a permanent, longitudinal displacement of a localized area of the pavement surface caused by traffic loading. When traffic pushes against the pavement, it produces a short, abrupt wave in the pavement surface. This distress normally occurs only in unstable liquid asphalt mix (cutback or emulsion) pavements.

Shoves also occur where asphalt pavements abut PCC pavements; the PCC pavements increase in length and push the asphalt pavement, causing the shoving.

Severity Levels: L – Shove causes low-severity ride quality. (Figure 61)

M – Shove causes medium-severity ride quality. (Figure 62)

H – Shove causes high-severity ride quality. (Figure 63)

How to Measure: Shoves are measured in square feet of surface area.

Shoves occurring in patches are considered in rating the patch, not as a separate distress.

Figure 61. Low-severity shoving.

Figure 62. Medium-severity shoving approaching high severity.

Figure 63. High-severity shoving.

Name of Distress: Slippage Cracking

Description: Slippage cracks are crescent or half-moon shaped cracks having two ends pointing away from the direction of traffic. They are produced when breaking or turning wheels cause the pavement surface to slide or deform. This distress usually occurs when there is a low-strength surface mix or a poor bond between the surface and the next layer of the pavement structure.

Severity Levels:

L - Average crack width is less than 3/8 in. (10 mm). (Figure 64)

M One of the following conditions exist (Figure 65):

1. Average crack width is between 3/8 and 1½ in. (10 and 38 mm)

2. The area around the crack is broken into tight-fitting pieces.

H One of the following conditions exist (Figure 66):

1. The average crack width is greater than 1½ in. (38 mm)

2. The area around the crack is broken into easily removed pieces.

How to Measure: The area associated with a given slippage crack is measured in square feet and rated according to the highest level severity in the area.

Figure 64. Low-severity slippage cracking.

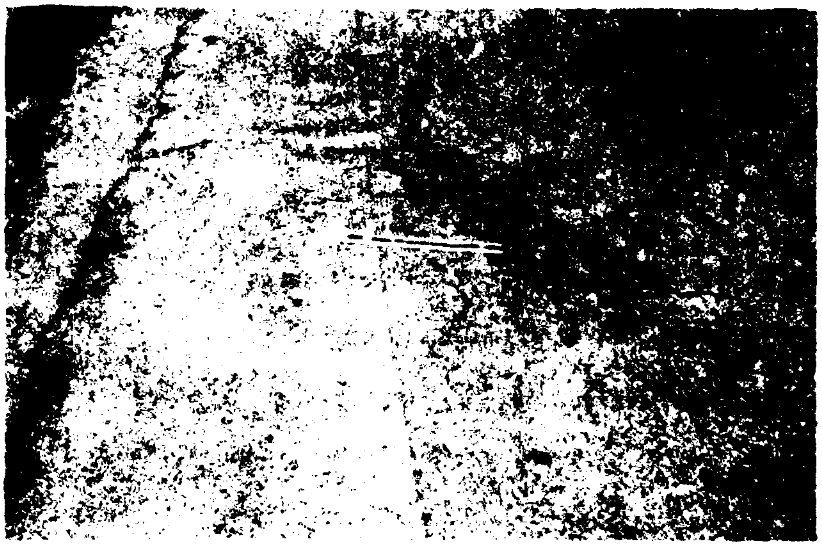

Figure 65. Medium-severity slippage cracking.

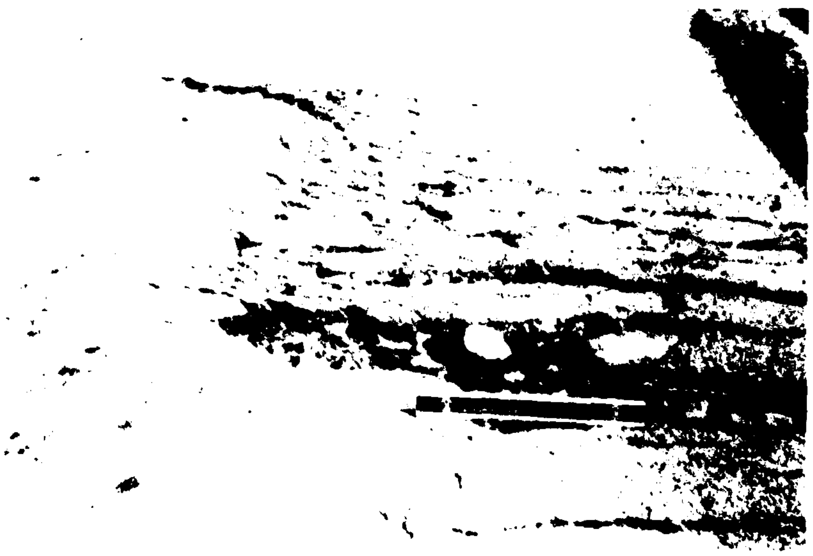

Figure 66. High-severity slippage cracking.

Name of Distress: Swell

Description: Swell is characterized by an upward bulge in the pavement's surface a long, gradual wave of more than 10 ft (3 m) long. Swelling can be accompanied by surface cracking. This distress is usually caused by frost action in the subgrade or by swelling soil.

Severity Levels:

L Swell causes low-severity ride quality. Low-severity swells are not always easy to see, but can be detected by driving at the speed limit over the pavement section. An upward acceleration will occur at the swell if it is present.

M Swell causes medium-severity ride quality.

H Swell causes high-severity ride quality.

See Figure 67.

How to Measure: The surface area of the swell is measured in square feet.

Figure 67. Example swell. Severity level is based on ride quality criteria.

Name of Distress: Weathering and Raveling

Description: Weathering and raveling are the wearing away of the pavement surface caused by the loss of asphalt or tar binder and dislodged aggregate particles. These distresses indicat that either the asphalt binder has hardened appreciably or that a poor quality mixture is present. In addition, raveling may be caused by certain types of traffic, e.g., tracked vehicles. Softening of the surface and dislodging of the aggregates due to oil spillage is also included under raveling.

Severity Levels:

L Aggregate or binder has started to wear away. In some areas, the surface is starting to pit. (Figures 68 and 69). In case of oil spillage, the oil stain can be seen, but the surface is hard and cannot be penetrated with a coin.

M - Aggregate and/or binder has worn away. The surface texture is moderately rough and pitted. (Figures 70 and 71). In case of oil spillage, the surface is soft and can be penetrated with a coin.

H - Aggregate and/or binder has been considerably worn away. The surface texture is very rough and severely pitted. The pitted areas are less than 4 in. (10 mm) in diameter and less than 1/2 in. (13 mm) deep; pitted areas larger than this are counted as potholes. (Figure 72). In case of oil spillage, the asphalt binder has lost its binding effect and the aggregate has become loose.

How to Measure: Weathering and raveling are measured in square feet of surface area.

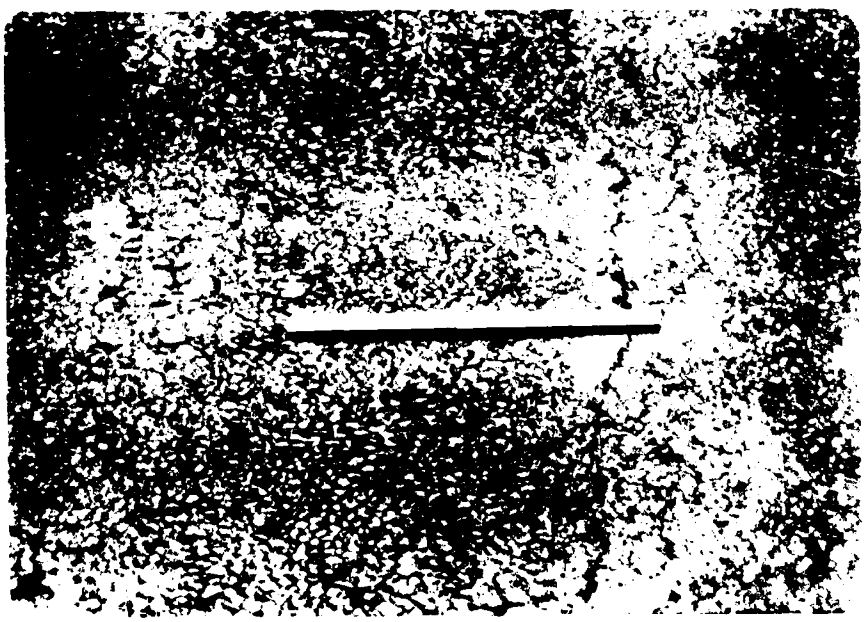

Figure 68. Low-severity weathering and raveling.

Figure 69. Low-severity weathering and raveling caused by tracked vehicles.

Figure 70. Medium-severity weathering and raveling.

Figure 71. Medium-severity weathering and raveling.

Figure 72. High-severity weathering and raveling.

Distress in Jointed Concrete Pavements

Nineteen distress types for jointed concrete pavements are listed alphabetically on pp 136 through 186. Distress definitions apply to both plain and reinforced jointed concrete pavements, with the exception of linear cracking distress, which is defined separately for plain and reinforced jointed concrete.

During the field condition surveys and validation of the PCI, several questions were often asked regarding the identification and counting method of some of the distresses. The answers to these questions are included under the section titled "How to Count" for each distress. For convenience, however, items that are frequently referenced are listed below:

1. Faulting is counted only at joints. Faulting associated with cracks is not counted separately since faulting is incorporated into the severity-level definitions of cracks. Crack definitions are also used in defining corner breaks and divided slabs.

2. Joint seal damage is not counted on a slab-by-slab basis. Instead, a severity level is assigned based on the overall condition of the joint seal in the area.

3. Cracks in reinforced concrete slabs that are less than 1/8 in. wide are counted as shrinkage cracks. Shrinkage cracks should not be counted to determine if the slab is broken into four or more pieces.

4. If the original distress of a patch is more severe than the patch, the original distress is the distress type recorded. For example, although patch material is present on the scaled area of the slab illustrated in Figure 73, only the scaling is counted.

5. Low-severity scaling (i.e., crazing) should only be counted if there is evidence that future scaling is likely to occur.

6. The severity level of blow-up and railroad distress in jointed concrete pavements is rated according to the distress' effect on ride quality.

The above is not intended to be a complete list. To properly measure each distress type, the inspector must be familiar with its individual criteria.

Figure 73. Distress in jointed concrete pavements.

ALPHABETICAL LISTING OF DISTRESS TYPES

DISTRESS TYPE–CONCRETE

Name of Distress: Blow-up Buckling

Description: Blow-ups or buckles occur in hot weather, usually at a transverse crack or joint that is not wide enough to permit slab expansion. The insufficient width is usually caused by infiltration of incompressible materials into the joint space. When expansion cannot relieve enough pressure, a localized upward movement of the slab edges (buckling) or shattering will occur in the vicinity of the joint. Blow-ups can also occur at utility cuts and drainage inlets.

Severity Levels:

L. Buckling or shattering causes low-severity ride quality. (Figure 74)

M Buckling or shattering causes medium-severity ride quality. (Figures 75 and 76)

H Buckling or shattering causes high-severity ride quality. (Figure 77)

How to Count: At a crack, a blow-up is counted as being in one slab. However, if the blow-up occurs at a joint and affects two slabs, the distress should be recorded as occurring in two slabs. When a blow-up renders the pavement inoperable, it should be repaired immediately.

Figure 74. Low-severity blow-up buckling.

Figure 75. Medium-severity blow-up, buckling.

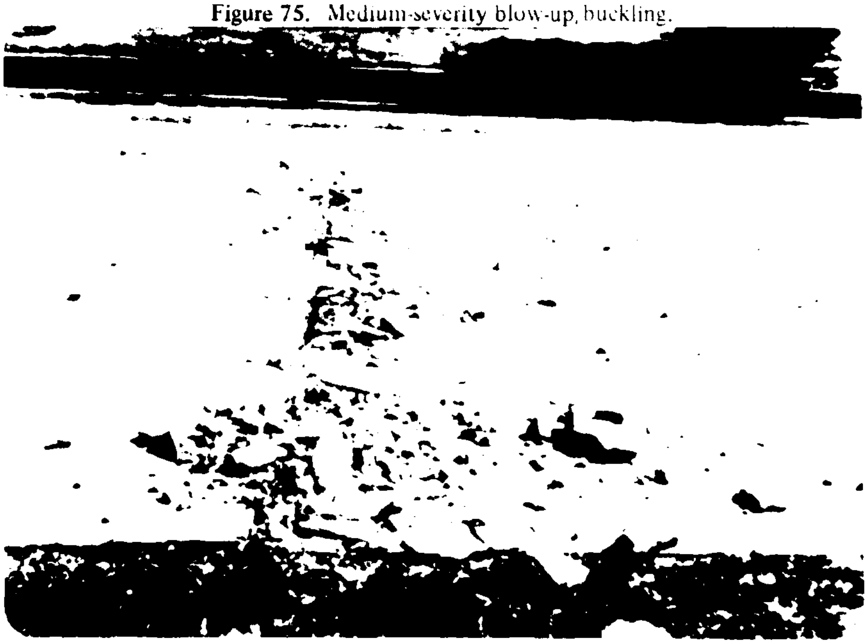

Figure 76. Medium-severity blow-up/buckling.

Figure 77. High-severity blow-up/buckling approaching inoperative condition.

Name of Distress: Corner Break

Description: A corner break is a crack that intersects the joints at a distance less than or equal to one-half the slab length on both sides, measured from the corner of the slab. For example, a slab with dimensions of 12 by 20 ft (3.7 by 6.1 m) that has a crack 5 ft (1.5 m) on one side and 12 ft (3.7 m) on the other side is not considered a corner break; it is a diagonal crack. However, a crack that intersects 4 ft (1.2 m) on one side and 8 ft (2.4 m) on the other is considered a corner break. A corner break differs from a corner spall in that the crack extends vertically through the entire slab thickness, while a corner spall intersects the joint at an angle. Load repetition combined with loss of support and curling stresses usually causes corner breaks.

Severity Levels:

L* – Break is defined by a low-severity crack and the area between the break and the joints is not cracked or may be lightly cracked. (Figures 78 and 79)

M* – Break is defined by medium-severity crack and or the area between the break and the joints is mediumly cracked. (Figure 80)

H* – Break is defined by a high-severity crack and/or the area between the break and the joints is highly cracked. (Figure 81)

How to Count: Distressed slab is recorded as one slab if it:

1. Contains a single corner break.

2. Contains more than one break of a particular severity.

3. Contains two or more breaks of different severities.

For two or more breaks, the highest level of severity should be recorded. For example, a slab containing both low- and medium-severity corner breaks should be counted as one slab with a medium corner break.

***See linear cracking for a definition of low-, medium-, and high-severity cracks.**

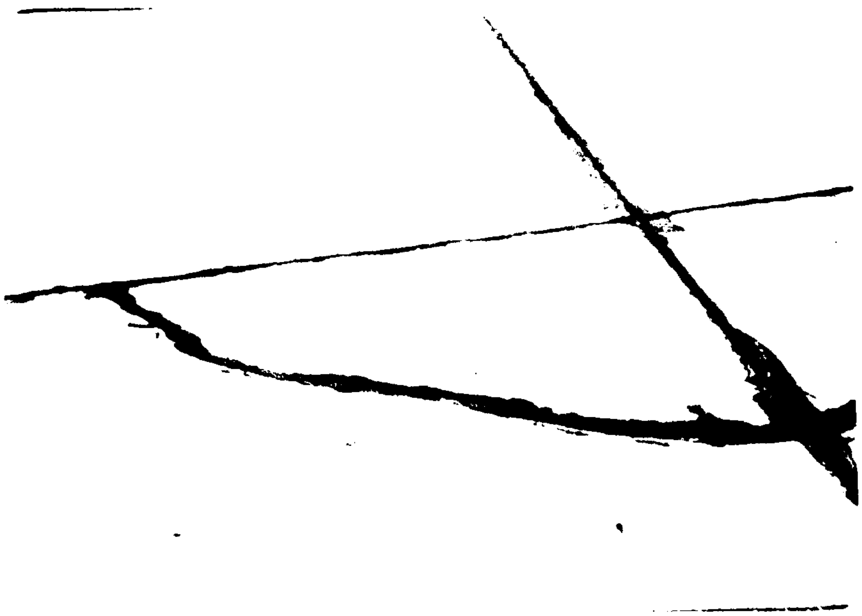

Figure 78. Low-severity corner break.

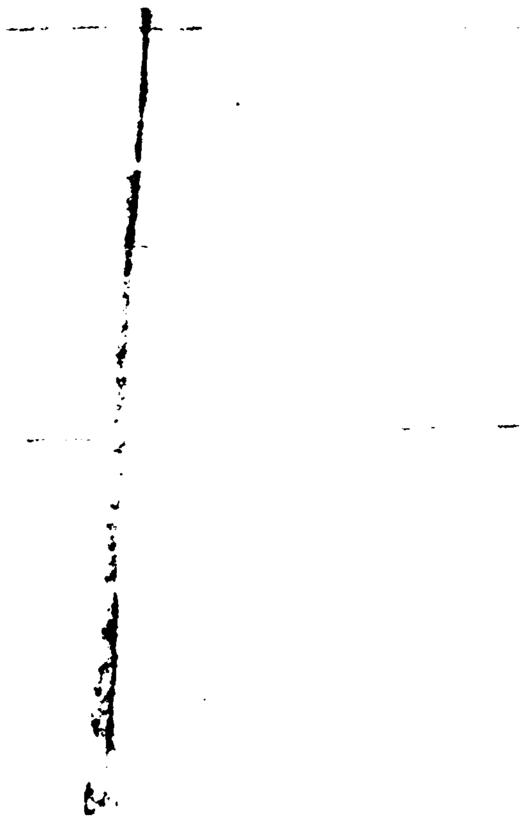

Figure 79. Low-severity corner break.

Figure 80. Medium-severity corner break. Defined by a medium-severity crack.

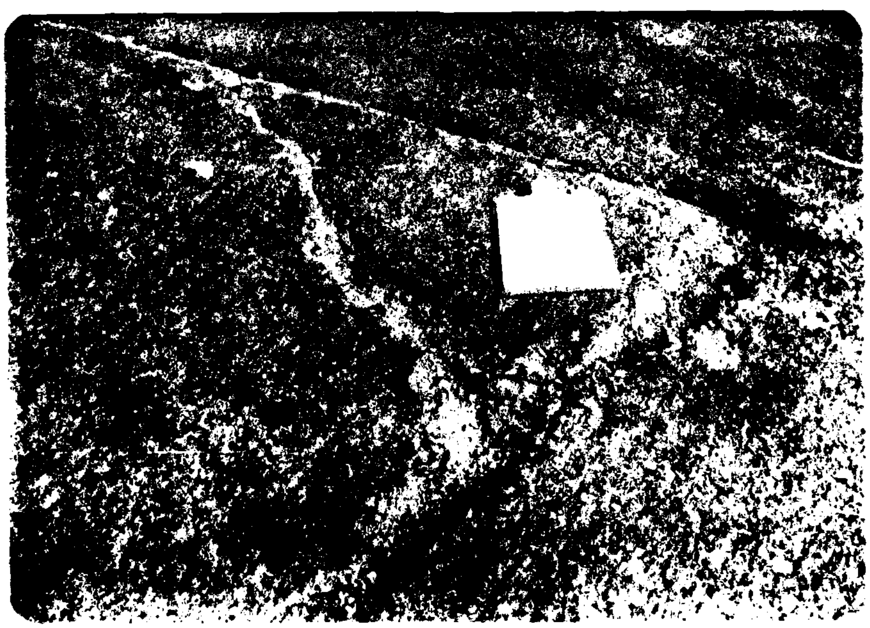

Figure 81. High-severity corner break.

Name of Distress: Divided Slab

Description: Slab is divided by cracks into four or more pieces due to overloading and/or inadequate support. If all pieces or cracks are contained within a corner break, the distress is categorized as a severe corner break.

Severity Levels:

Severity of Majority of Cracks	Number of Pieces in Cracked Slab: 4 to 5	6 to 8	More than 8
L	L	L	M
M	M	M	H
H	M	H	H

See Figures 82 through 86.

How to Count: If the slab is medium or high severity, no other distress is counted.

Figure 82. Low-severity divided slab. Majority of cracks are low severity (less than ½ in. wide and no faulting).

Figure 83. Medium-severity divided slab.

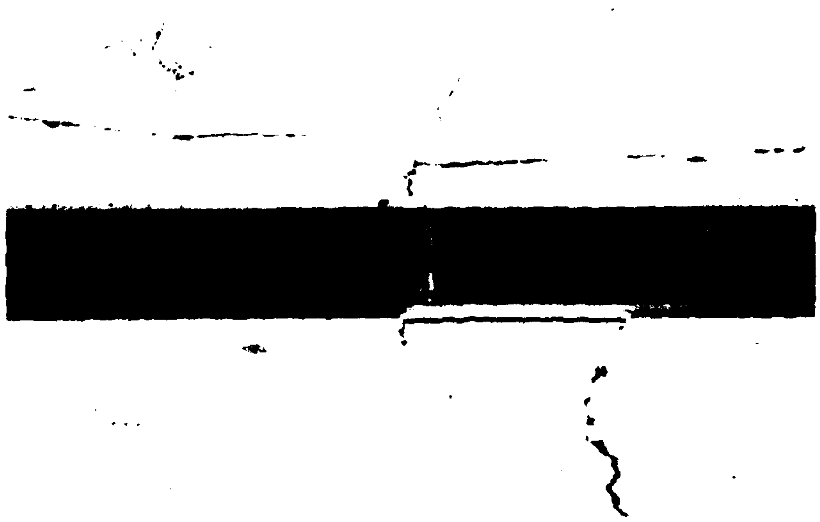

Figure 84. High-severity divided slab caused by high-severity cracks.

Figure 85. High-severity divided slab.

Figure 86. High-severity divided slab.

Name of Distress: Durability ("D") Cracking

Description: "D" cracking is caused by freeze-thaw expansion of the large aggregate which over time gradually breaks down the concrete. This distress usually appears as a pattern of cracks running parallel and close to a joint or linear crack. Since the concrete becomes saturated near joints and cracks, a dark-colored deposit can usually be found around fine "D" cracks. This type of distress may eventually lead to disintegration of the entire slab.

Severity Levels:

L – "D" cracks cover less than 15 percent of slab area. Most of the cracks are tight, but a few pieces may have popped out. (Figures 87 and 88)

M One of the following conditions exist (Figure 89):

1. "D" cracks cover less than 15 percent of the area and most of the pieces have popped out or can be easily removed.

2. "D" cracks cover more than 15 percent of the area. Most of the cracks are tight, but a few pieces may have popped out or can be easily removed.

H – "D" cracks cover more than 15 percent of the area and most of the pieces have popped out or can be easily removed. (See Figures 90 and 91)

How to Count: When the distress is located and rated at one severity, it is counted as one slab. If more than one severity level exists, the slab is counted as having the higher severity distress. For example, if low and medium "D" cracking are on the same slab, the slab is counted as having medium-severity cracking only.

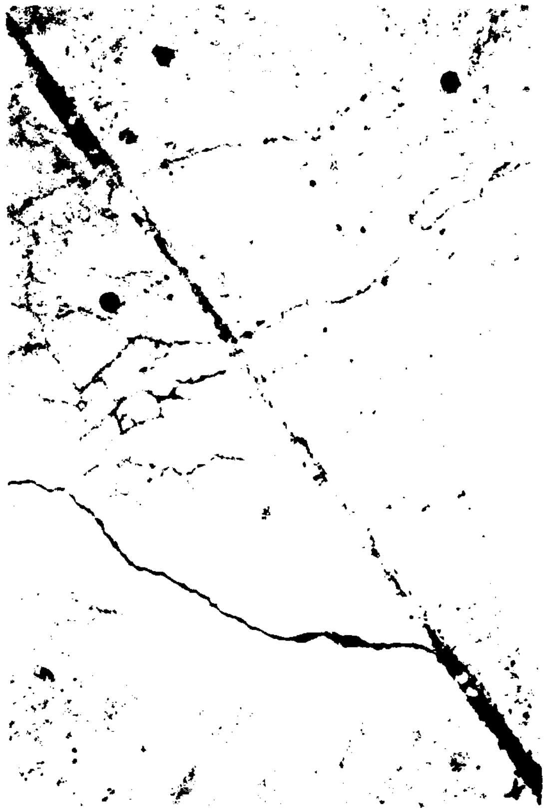

Figure 87. Low-severity durability cracking.

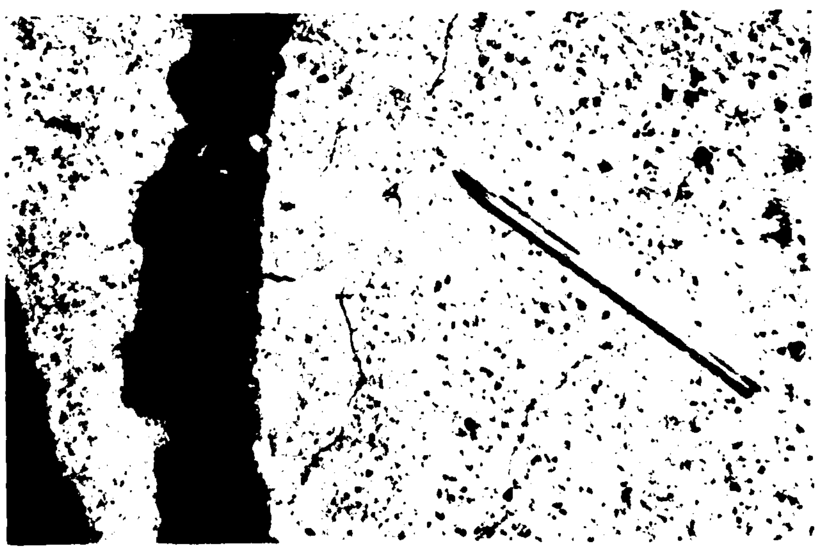

Figure 88. Low-severity durability cracking.

Figure 89. Medium-severity durability cracking.

Figure 90. High-severity durability cracking.

Figure 91. High-severity durability cracking.

Name of Distress: Faulting

Description: Faulting is the difference in elevation across a joint. Some of the common causes of faulting are:

1. Settlement because of soft foundation.

2. Pumping or eroding of material from under the slab.

3. Curling of the slab edges due to temperature and moisture changes.

Severity Levels: Severity levels are defined by the difference in elevation across the crack or joint.

Severity Level	Difference in Elevation
L	1/8 to ≤ 3/8 in. (3 to ≤ 10 mm)
M	> 3/8 to ≤ 3/4 in. (> 10 to ≤ 19 mm)
H	> 3/4 in. (> 19 mm)

See Figures 92 through 95.

How to Count: Faulting across a joint is counted as one slab. Only affected slabs are counted.

Faults across a crack are not counted as distress, but are considered when defining crack severity.

Figure 92. Low-severity faulting.

Figure 93. Medium-severity faulting.

Figure 94. Medium-severity faulting.

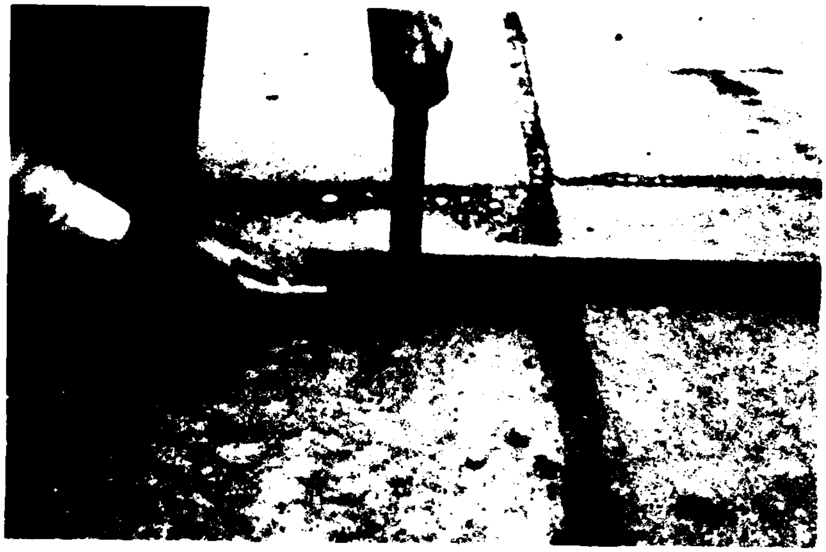

Figure 95. High-severity faulting.

Name of Distress: Joint Seal Damage

Description: Joint seal damage is any condition which enables soil or rocks to accumulate in the joints or allows significant water infiltration. Accumulation of incompressible materials prevents the slabs from expanding and may result in buckling, shattering, or spalling. A pliable joint filler bonded to the edges of the slabs protects the joints from material accumulation and prevents water from seeping down and softening the foundation supporting the slab.

Typical types of joint seal damage are:

1. Stripping of joint sealant.

2. Extrusion of joint sealant.

3. Weed growth.

4. Hardening of the filler (oxidation).

5. Loss of bond to the slab edges.

6. Lack or absence of sealant in the joint.

Severity Levels:

L – Joint sealant is in generally good condition throughout the section. Sealant is performing well, with only minor damage (see above). (Figure 96)

M – Joint sealant is in generally fair condition over the entire section, with one or more of the above types of damage occurring to a moderate degree. Sealant needs replacement within 2 years. (Figure 97)

H – Joint sealant is in generally poor condition over the entire section, with one or more of the above types of damage occurring to a severe degree. Sealant needs immediate replacement. (Figure 98 and 99)

How to Count: Joint seal damage is not counted on a slab-by-slab basis, but rated based on the overall condition of the sealant over the entire area.

Figure 96. Low-severity joint seal damage.

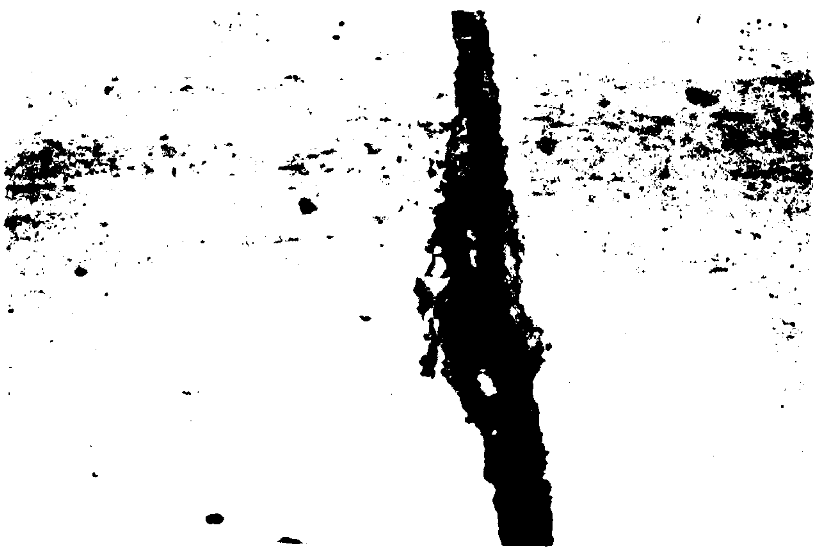

Figure 97. Medium-severity joint seal damage.

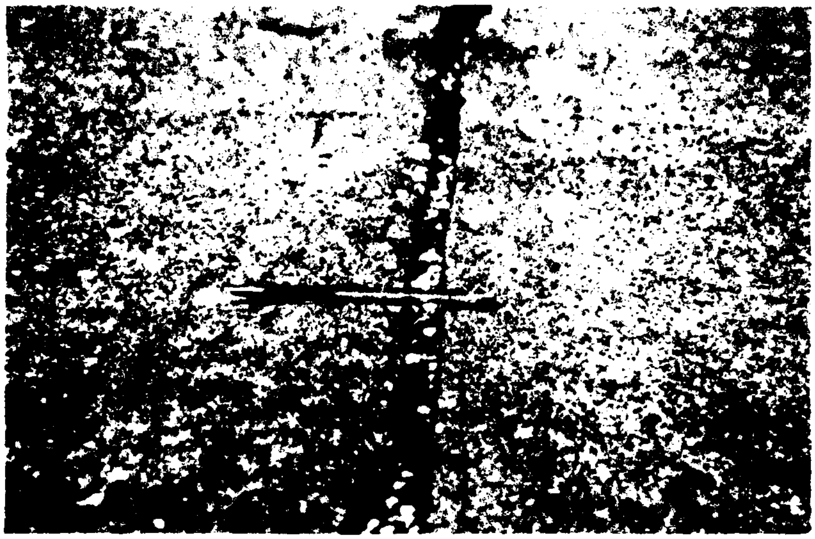

Figure 98. High-severity joint seal damage.

Figure 99. High-severity joint seal damage.

Name of Distress: Lane/Shoulder Drop Off

Description: Lane/shoulder drop off is the difference between the settlement or erosion of the shoulder and the pavement travel-lane edge. The elevation difference can be a safety hazard; it can also cause increased water infiltration.

Severity Levels:

L The difference between the pavement edge and shoulder is 1 to 2 in. (25 to 51 mm). (Figure 100)

M - The difference in elevation is 2 to 4 in. (51 to 102 mm). (Figure 101)

H - The difference in elevation is greater than 4 in. (102 mm) (Figure 102)

How to Count: The mean lane/shoulder drop off is computed by averaging the maximum and minimum drop along the slab. Each slab exhibiting distress is measured separately and counted as one slab with the appropriate severity level.

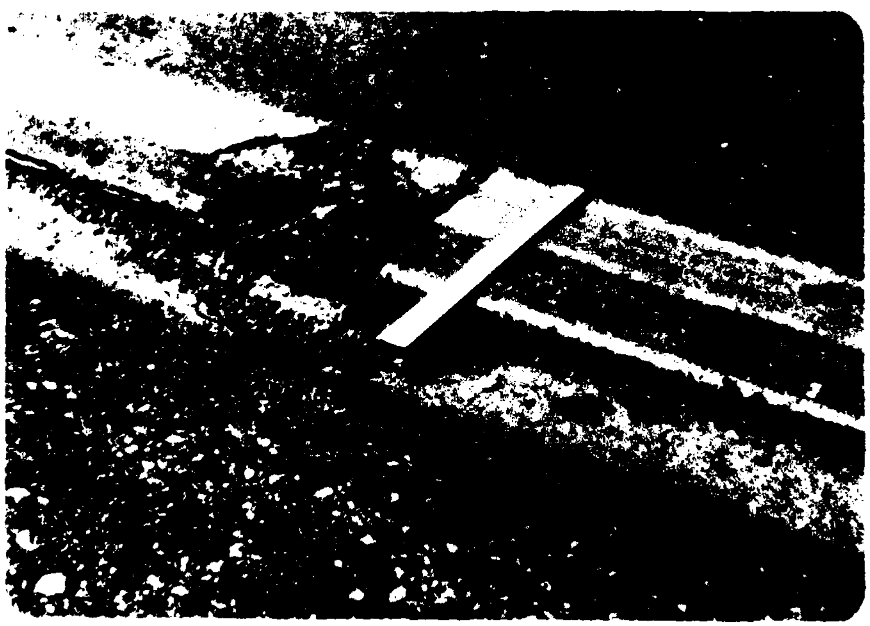

Figure 100. Low-severity lane/shoulder drop off.

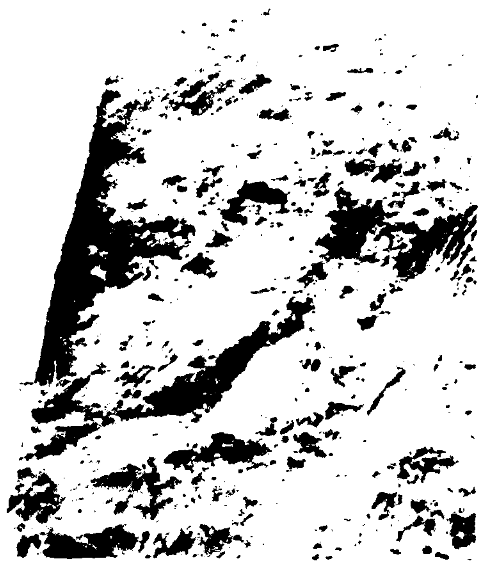

Figure 101. Medium-severity lane/shoulder drop off.

Figure 102. High-severity lane/shoulder drop off.

Name of Distress: Linear Cracking (Longitudinal, Transverse, and Diagonal Cracks)

Description: These cracks, which divide the slab into two or three pieces, are usually caused by a combination of repeated traffic loading, thermal gradient curling, and repeated moisture loading. (Slabs divided into four or more pieces are counted as Divided Slabs). Low-severity cracks are usually related to warp or friction and are not considered major structural distresses. Medium- or high-severity cracks are usually working cracks and are considered major structural distresses. (Figures 103 through 108)

Hairline cracks that are only a few feet long and do not extend across the entire slab are counted as shrinkage cracks.

Severity Levels: *Nonreinforced Slabs*

L Nonfilled* cracks less than or equal to 1/2 in. (12 mm) or filled cracks of any width with the filler in satisfactory condition. No faulting exists.

M – One of the following conditions exists:

1. Nonfilled crack with a width between 1/2 and 2 in. (12 and 51 mm).

2. Nonfilled crack of any width up to 2 in. (51 mm) with faulting of less than 3/8 in. (10 mm).

3. Filled crack of any width with faulting less than 3/8 in. (10 mm).

H - One of the following conditions exist:

1. Nonfilled crack with a width greater than 2 in. (51 mm).

2. Filled or nonfilled crack of any width with faulting greater than 3/8 in. (10 mm).

Reinforced Slabs

L – Nonfilled cracks with a width of 1/8 to 1 in. (3 to 25 mm); filled crack of any width with the filler in satisfactory condition. No faulting exists.

M – One of the following conditions exist:

1. Nonfilled cracks with a width between 1 and 3 in. (25 and 76 mm) and no faulting.

2. Nonfilled crack of any width up to 3 in. (76 mm) with up to 3/8 in. (10 mm) of faulting.

3. Filled crack of any width with up to 3/8 in. (10 mm) faulting.

H – One of the following conditions exist:

1. Nonfilled crack with width over 3 in. (76 mm).

2. Filled or nonfilled crack of any width with faulting over 3/8 in. (10 mm).

---

*Filled cracks where filler is unsatisfactory are treated as nonfilled.

How to Count: Once the severity has been identified, the distress is recorded as one slab. If two medium-severity cracks are within one slab, the slab is counted as having one high-severity crack. Slabs divided into four or more pieces are counted as divided slabs.

In reinforced slabs, cracks with a width less than 1/8 in. (3 mm) are counted as shrinkage c' icks. Slabs longer than 30 ft (9.1 m) are divided into approximately equal length abs" having imaginary joints assumed to be in perfect condition.

Figure 103. Low-severity linear cracking in a nonreinforced concrete slab.

Figure 104. Low-severity linear cracking in a nonreinforced concrete slab.

Figure 105. Medium-severity linear cracking in a reinforced concrete slab.

Figure 106. Medium-severity linear cracking in a reinforced concrete slab.

Figure 107. High-severity linear cracking in a nonreinforced concrete slab.

Figure 108. High-severity linear cracking in a nonreinforced concrete slab.

Name of Distress: Patching, Large [more than 5 sq ft (.45 m^2)] and Utility Cuts

Description: A patch is an area where the original pavement has been removed and replaced by a filler material. A utility cut is a patch that has replaced the original pavement to allow the installation or maintenance of underground utilities. The severity levels of a utility cut are the same as those for regular patching.

Severity Levels:

L – Patch is functioning well, with little or no deterioration. (Figures 109 and 110)

M – Patch is moderately deteriorated and/or moderate spalling can be seen around the edges. Patch material can be dislodged with considerable effort. (Figures 111 through 113)

H – Patch is badly deteriorated. The extent of the deterioration warrants replacement of the patch. (Figure 114)

How to Count: If a single slab has one or more patches with the same severity level, it is counted as one slab containing that distress. If a single slab has more than one severity level, it is counted as one slab with the higher severity level.

If the cause of the patch is more severe, only the original distress is counted.

Figure 109. Low-severity patching, large and utility cuts.

Figure 110. Low-severity patching, large and utility cuts.

Figure 111. Medium-severity patching, large.

Figure 112. Medium-severity patching, large.

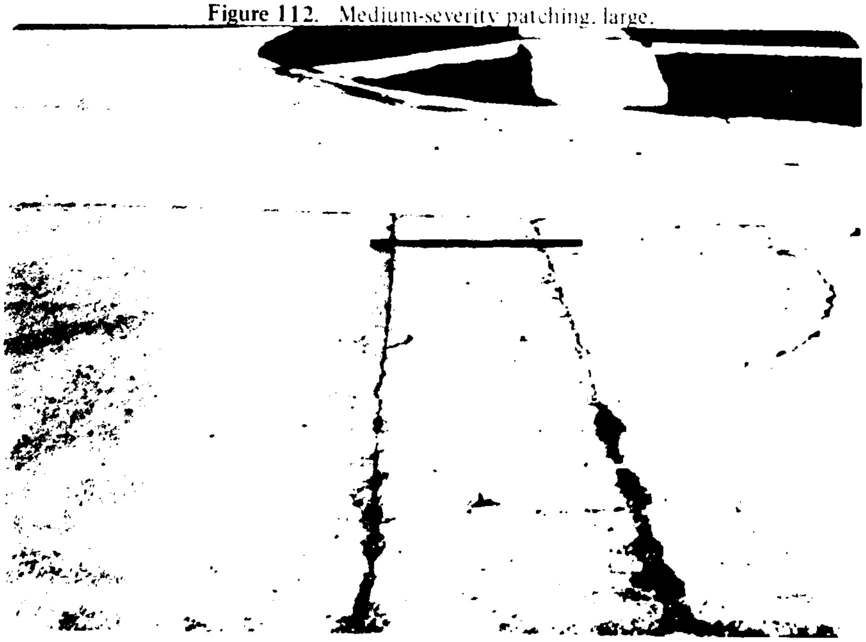

Figure 113. Medium-severity patching, utility cuts.

Figure 114. High-severity patching, large.

Name of Distress: Patching, Small [less than 5 sq ft (.45 m^2)]

Description: A patch is an area where the original pavement has been removed and replaced by a filler material.

Severity Levels:

L – Patch is functioning well with little or no deterioration. (Figure 115)

M – Patch is moderately deteriorated. Patch material can be dislodged with considerable effort. (Figure 116)

H – Patch is badly deteriorated. The extent of deterioration warrants replacement of the patch. (Figure 117)

How to Count: If a single slab has one or more patches with the same severity level, it is counted as one slab containing that distress. If a single slab has more than one severity level, it is counted as one slab with the higher severity level.

If the cause of the patch is more severe, only the original distress is counted.

Figure 115. Low-severity patching, small.

Figure 116. Medium-severity patching, small.

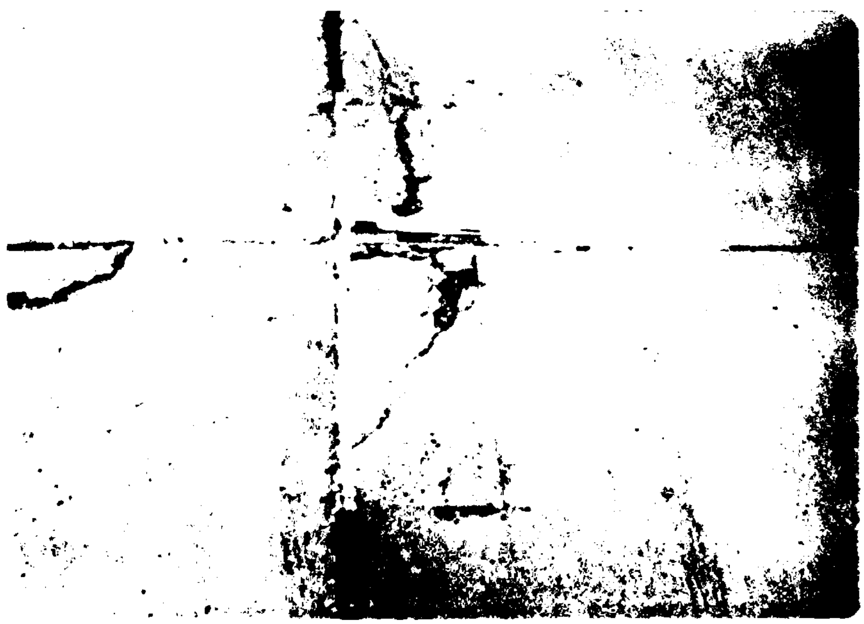

Figure 117. High-severity patching, small.

Name of Distress: Polished Aggregate

Description: This distress is caused by repeated traffic applications. When the aggregate in the surface becomes smooth to the touch, adhesion with vehicle tires is considerably redu . When the portion of aggregate extending above the surface is small, the pavement texture does not significantly contribute to reducing vehicle speed. Polished aggregate should be counted when close examination reveals that the aggregate extending above the concrete is negligible, and the surface aggregate is smooth to the touch. This type of distress is indicated when the number on a skid resistance test is low or has dropped significantly from previous ratings.

Severity Levels: No degrees of severity are defined. However, the degree of polishing should be significant before it is included in the condition survey and rated as a defect. (Figure 118)

How to Count: A slab with polished aggregate is counted as one slab.

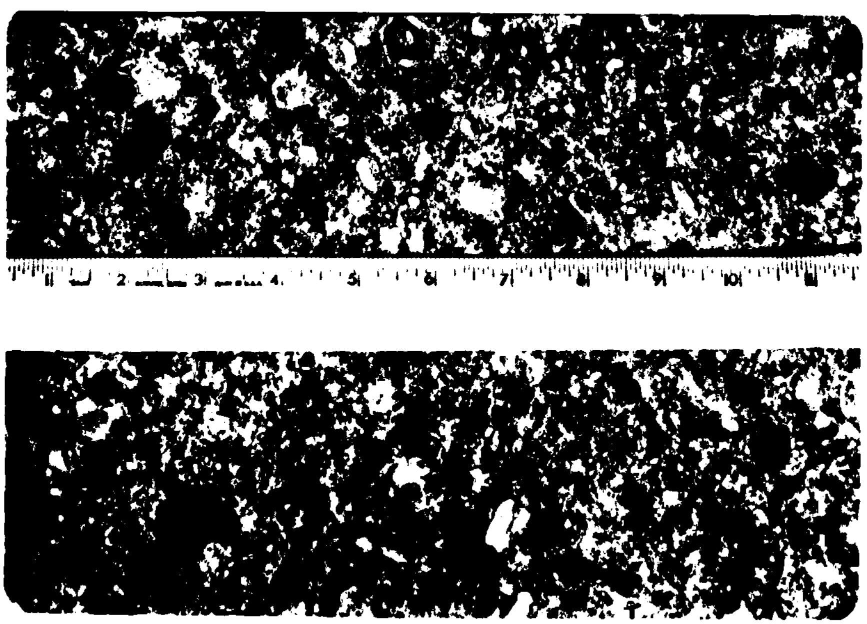

Figure 118. Polished aggregate.

Name of Distress: Popouts

Description: A popout is a small piece of pavement that freeze-thaw action combined with aggregate expansion causes to break loose from the surface. Popouts usually range in diameter from approximately 1 to 4 in. (25 to 102 mm) and in depth from 1/2 to 2 in. (13 to 51 mm).

Severity Levels: No degrees of severity are defined for popouts. However, popouts must be extensive before they are counted as a distress. Average popout density must exceed approximately three popouts per square yard over the entire slab area. (Figure 119)

How to Count: The density of the distress must be measured. If there is any doubt that the average is greater than three popouts per square yard, at least three random 1 sq yd (.84 m^2) areas should be checked. When the average is greater than this density, the slab should be counted.

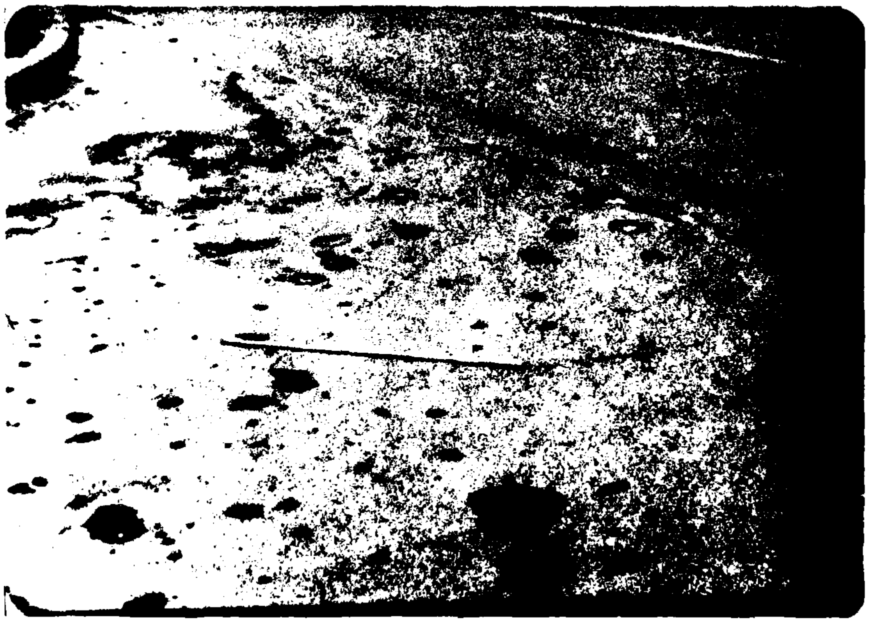

Figure 119. Popouts.

Name of Distress:	Pumping
Description:	Pumping is the ejection of material from the slab foundation through joints or cracks. This is caused by deflection of the slab by passing loads. As a load moves across the joint between the slabs, water is first forced under the leading slab, and then forced back under the trailing slab. This erodes and eventually removes soil particles, resulting in progressive loss of pavement support. Pumping can be identified by surface stains and evidence of base or subgrade material on the pavement close to joints or cracks. Pumping near joints is caused by poor joint sealer and indicates loss of support; repeated loading will eventually produce cracks. Pumping can also occur along the slab edge, causing loss of support.
Severity Levels:	No degrees of severity are defined. It is sufficient to indicate the pumping exists. (Figures 120 and 121)
How to Count:	One pumping joint between two slabs is counted as two slabs. However, if the remaining joints around the slab are also pumping, one slab is added per additional pumping joint.

Figure 120. Pumping.

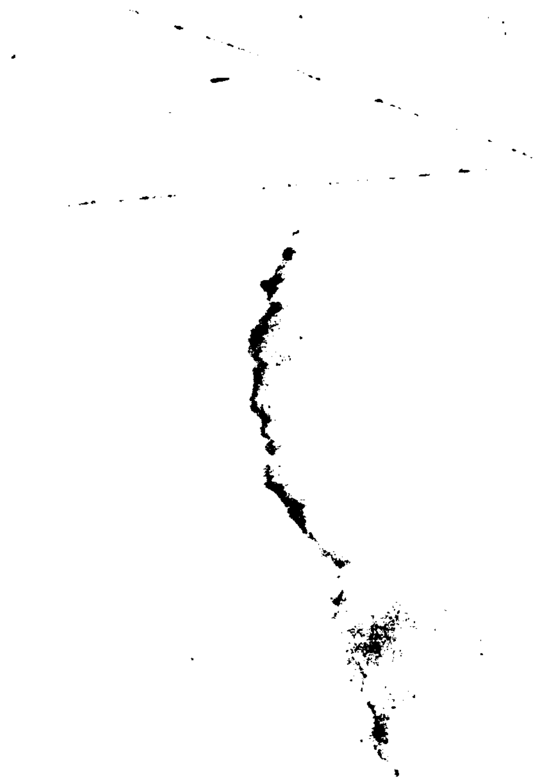

Figure 121. Pumping.

Name of Distress: Punchout

Description: This distress is a localized area of the slab that is broken into pieces. The punchout can take many different shapes and forms, but it is usually defined by a crack and a joint, or two closely spaced cracks [usually 5 ft (1.52 m) wide]. This distress is caused by heavy repeated loads, inadequate slab thickness, loss of foundation support, and/or a localized concrete construction deficiency (e.g., honeycombing).

Severity Levels:

Majority of Cracks Severity	Number of Pieces 2 to 3	4 to 5	> 5
L	L	L	M
M	L	M	H
H	M	H	H

See Figures 122 through 124.

How to Count: If a slab contains one or more punchouts, it is counted as containing a punchout at the severity level of the most severe punchout.

Figure 122. Low-severity punchout.

Figure 123. Medium-severity punchout approaching high severity.

Figure 124. High-severity punchout.

Name of Distress: Railroad Crossing

Description: Railroad crossing distress is characterized by depressions or bumps around the tracks.

Severity Levels:

L - Railroad crossing causes low-severity ride quality. (Figure 125)

M Railroad crossing causes medium-severity ride quality. (Figure 126)

H Railroad crossing causes high-severity ride quality. (Figure 127)

How to Count: The number of slabs crossed by the railroad track is counted. Any large bump created by the tracks should be counted as part of the crossing.

Figure 125. Low-severity railroad crossing.

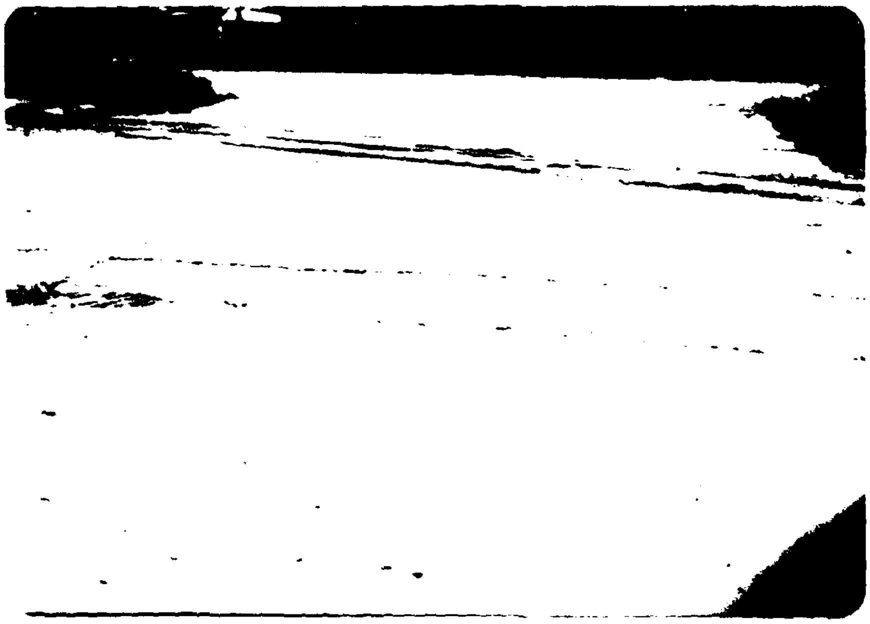

Figure 126. Medium-severity railroad crossing.

Figure 127. High-severity railroad crossing.

Name of Distress: Scaling/Map Cracking/Crazing

Description. Map cracking or crazing refers to a network of shallow, fine, or hairline cracks which extend only through the upper surface of the concrete. The cracks tend to intersect at angles of 120 degrees. Map cracking or crazing is usually caused by concrete over-finishing, and may lead to surface scaling, which is the breakdown of the slab surface to a depth of approximately 1/4 to 1/2 in. (6 to 13 mm). Scaling may also be caused by deicing salts, improper construction, freeze-thaw cycles, and poor aggregate. The type of scaling defined here is not caused by "D" cracking. If scaling is caused by "D" cracking, it should be counted under that distress only.

Severity Levels:

L - Crazing or map cracking exists over most of the slab area; the surface is in good condition, with only minor scaling present. (Figure 128)

M - Slab is scaled, but less than 15 percent of the slab area is affected. (Figure 129)

H - Slab is scaled over more than 15 percent of its area. (Figures 130 through 132)

How to Count: A scaled slab is counted as one slab. Low-severity crazing should only be counted if the potential for scaling appears to be imminent, or few small pieces have come out.

Figure 128. Low-severity scaling/map cracking/crazing.

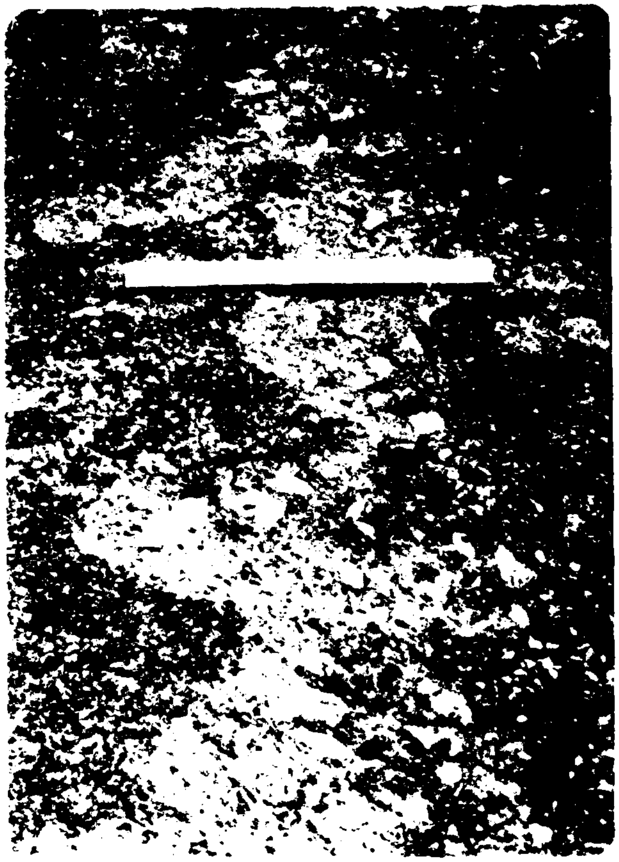

Figure 129. Medium severity scaling/map cracking/crazing

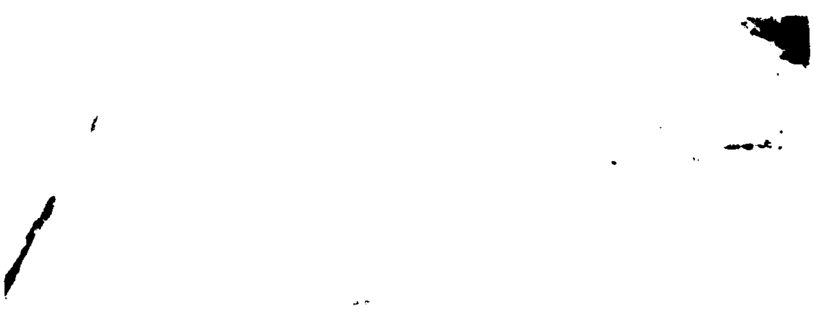

Figure 130. High severity scaling/map cracking/crazing

Figure 131. High-severity scaling/map cracking/crazing.

Figure 132. High-severity scaling/map cracking/crazing.

Name of Distress: Shrinkage Cracks

Description: Shrinkage cracks are hairline cracks that are usually only a few feet long and do not extend across the entire slab. They are formed during the setting and curing of the concrete and usually do not extend through the depth of the slab.

Severity Levels: No degrees of severity are defined. It is enough to indicate that shrinkage cracks are present. (Figure 133)

How to Count: If one or more shrinkage cracks exist on one particular slab, the slab is counted as one slab with shrinkage cracks.

Figure 133. Shrinkage cracks.

Name of Distress: Spalling, Corner

Description: Corner spalling is the breakdown of the slab within approximately 2 ft (.6 m) of the corner. A corner spall differs from a corner break in that the spall usually angles downward to intersect the joint, while a break extends vertically through the slab corner. Spalls less than 5 in. (13 mm) from the crack to the corner on both sides should not be counted.

Severity Levels:

Corner Spalling

Dimensions of Sides of Spall

Depth of Spall	5 x 5 in. to 12 x 12 in. (13 x 13 mm) (31 x 31 mm)	Over 12 x 12 in. (31 x 31 mm)
< 1 in. (25 mm)	L	L
> 1 to ≤ 2 in. (> 25 to ≤ 51 mm)	L	M
> 2 in. (51 mm)	M	H

Corner spalling having an area of less than 10 sq in. (516 mm^2) is not counted. (Figures 134 through 137)

How to Count: If one or more corner spalls with the same severity level are in a slab, the slab is counted as one slab with corner spalling. If more than one severity level occurs, it is counted as one slab with the higher severity level.

Figure 134. Low-severity spalling, corner.

Figure 135. Low-severity spalling, corner.

Figure 136. Medium-severity spalling, corner.

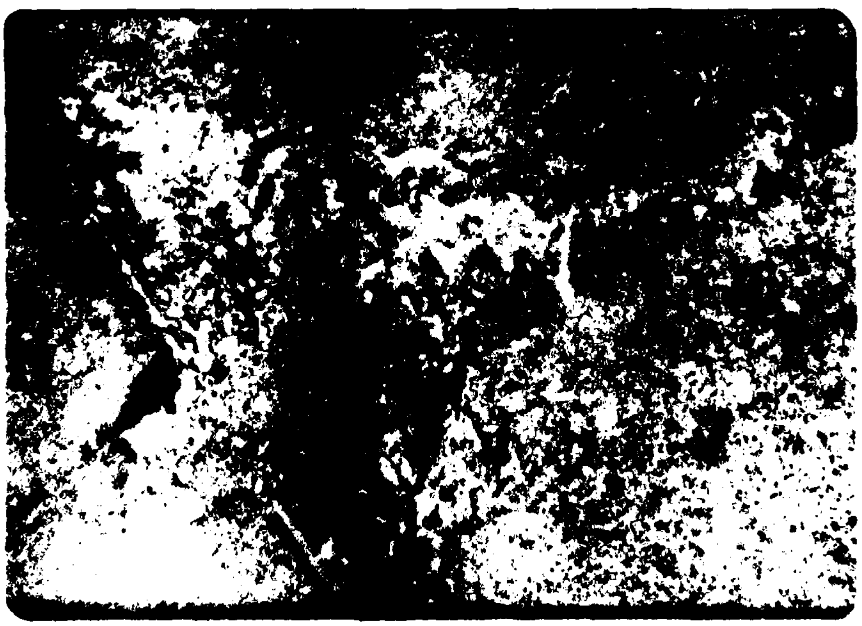

Figure 137. High-severity spalling, corner.

Name of Distress: Spalling, Joint

Description: Joint spalling is the breakdown of the slab edges within 2 ft (.6 m) of the joint. A joint spall usually does not extend vertically through the slab, but intersects the joint at an angle. Spalling results from:

1. Excessive stresses at the joint caused by traffic loading or by infiltration of incompressible materials.

2. Weak concrete at the joint caused by overworking.

3. Water accumulation in the joint and freeze-thaw action.

Severity Levels:

Joint Spalling

Spall Pieces	Width of Spall	Length of Spall < 2 ft (.6 m)	Length of Spall > 2 ft (.6 m)
Tight – cannot be easily removed (may be a few pieces missing).	≤ 4 in. (102 mm)	L	L
	> 4 in.	L	L
Loose – can be removed and some pieces are missing; if most or all pieces are missing, spall is shallow, less than 1 in. (25 mm).	≤ 4 in. (102 mm)	L	M
	> 4 in. (102 mm)	L	M
Missing – most or all pieces have been removed.	≤ 4 in. (102 mm)	L	M
	> 4 in. (102 mm)	M	H

See Figures 138 through 140.

A frayed joint where the concrete has been worn away along the entire joint is rated as low severity.

How to Count: If the spall is along the edge of one slab, it is counted as one slab with joint spalling. If spalling is on more than one edge of the same slab, the edge having the highest severity is counted and recorded as one slab. Joint spalling can also occur along the edges of two adjacent slabs. If this is the case, each slab is counted as having joint spalling.

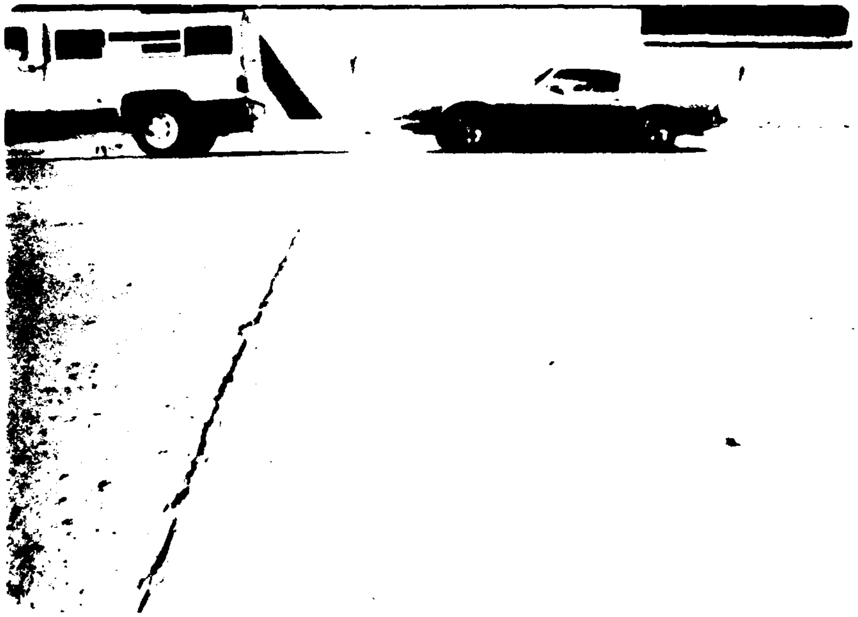

Figure 138. Low-severity spalling, joint.

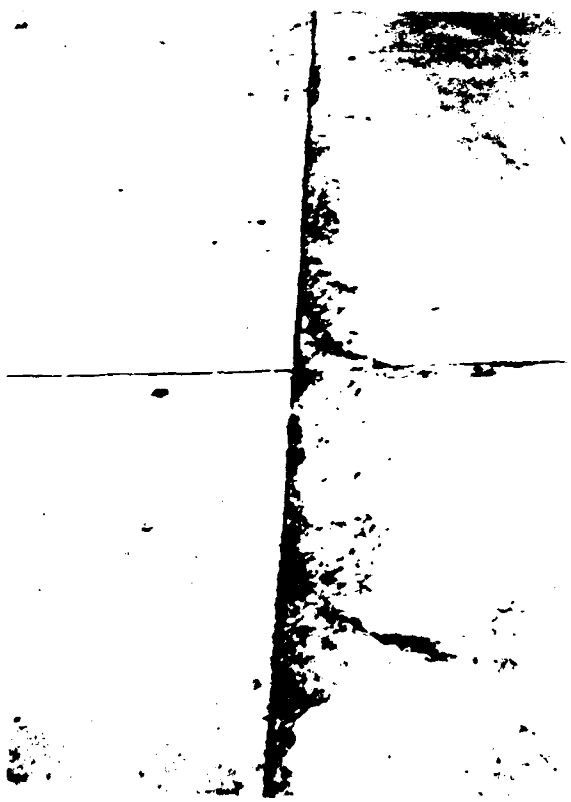

Figure 139. Medium-severity spalling, joint.

Figure 140. High-severity spalling, joint.

APPENDIX B

DEDUCT VALUE CURVES

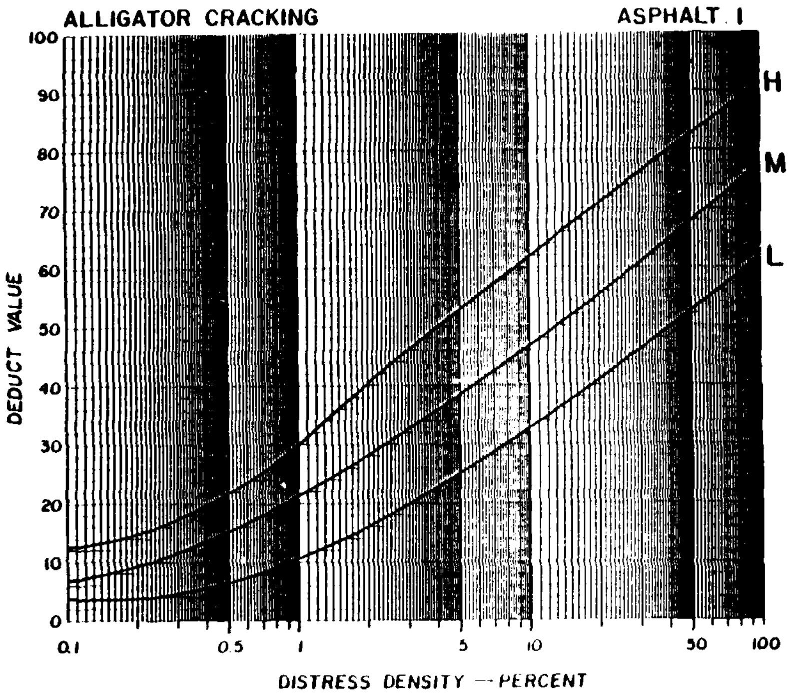

Figure B1. Alligator cracking.

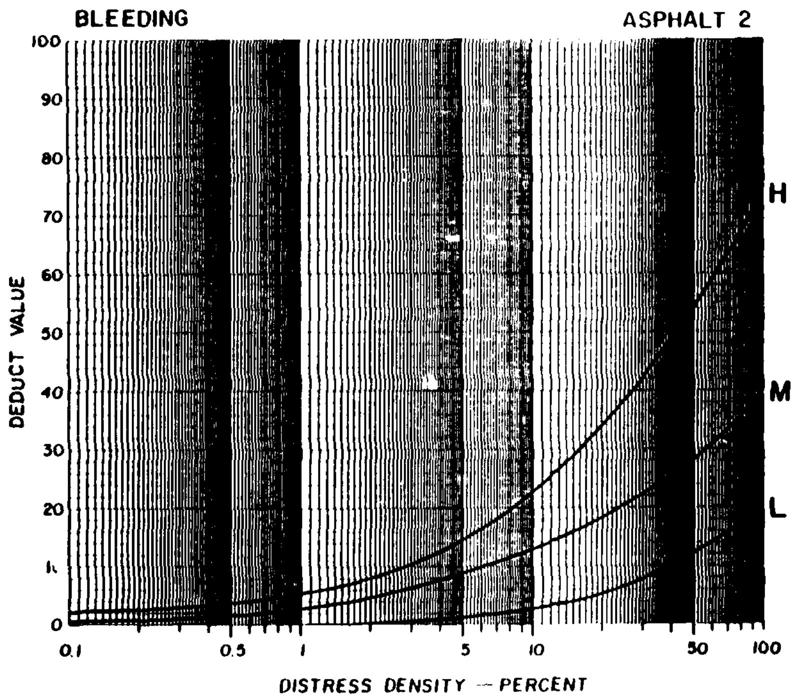

Figure B2. Bleeding.

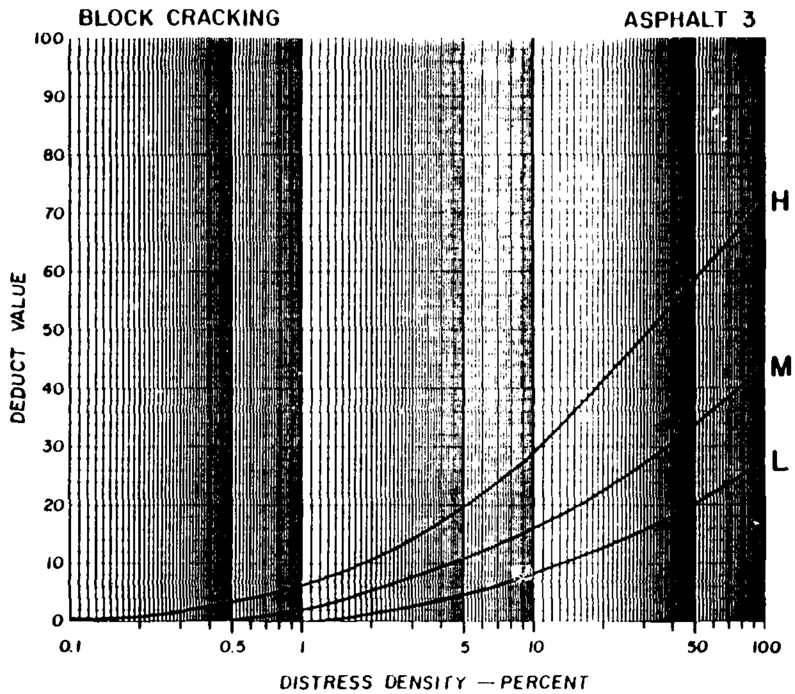

Figure B3. Block cracking.

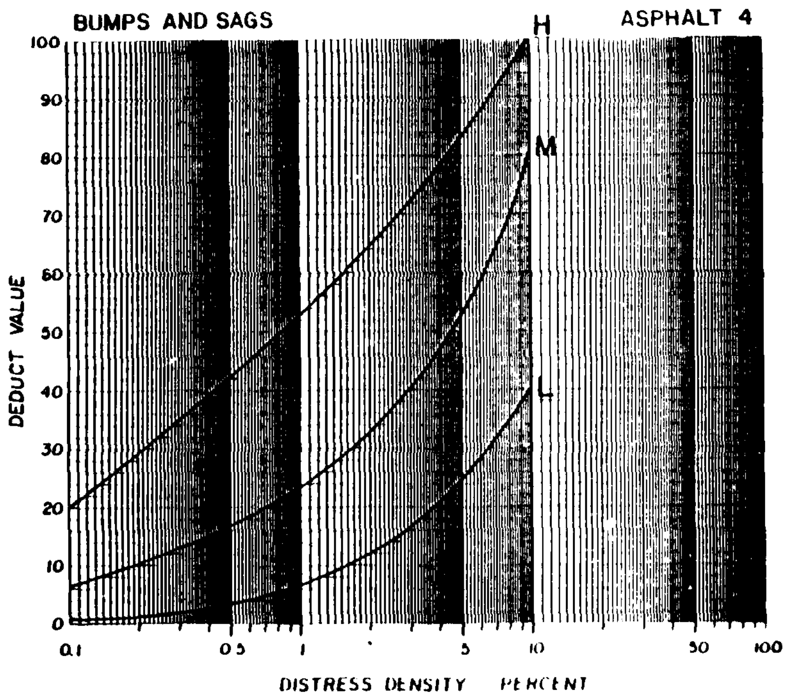

Figure B4. Bumps and sags.

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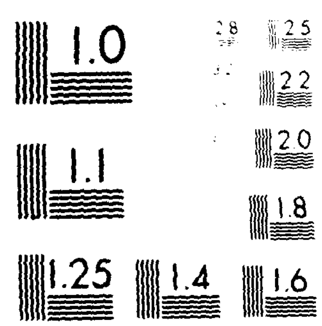

MICROCOPY RESOLUTION TEST CHART

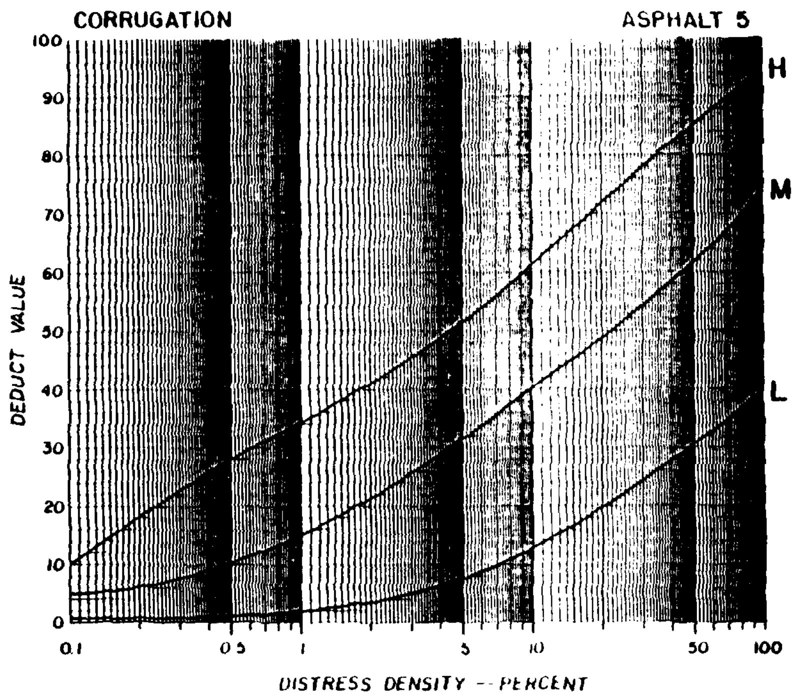

Figure B5. Corrugation.

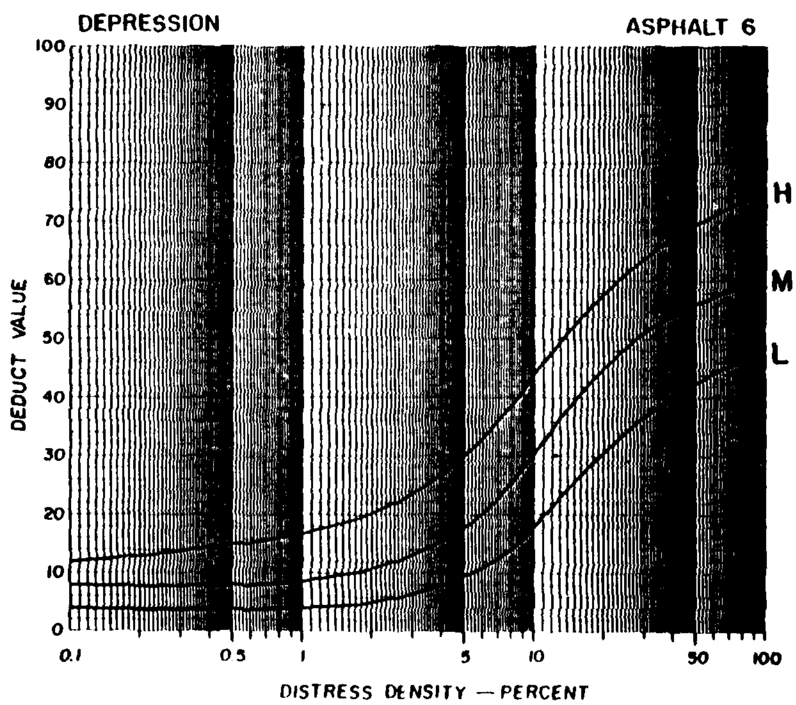

Figure B6. Depression.

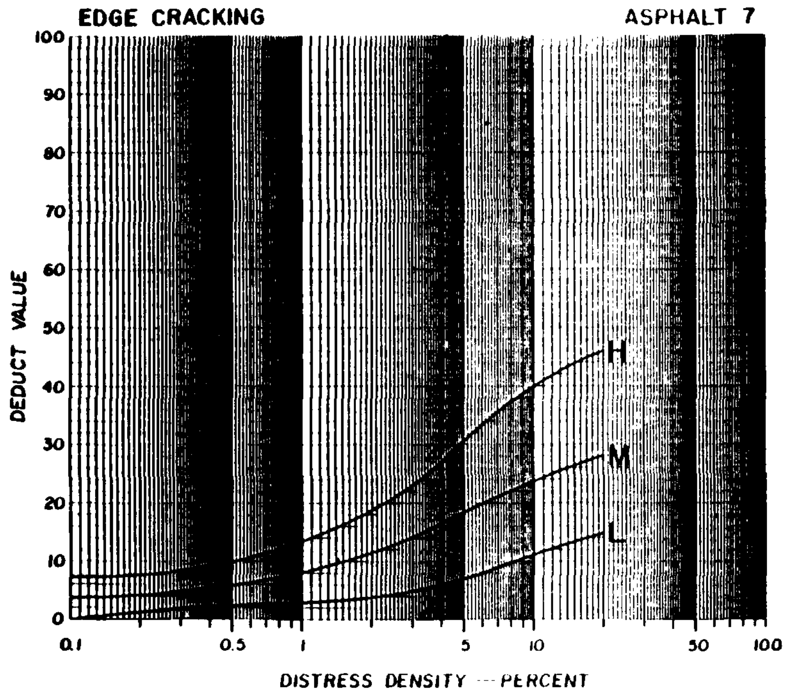

Figure B7. Edge cracking.

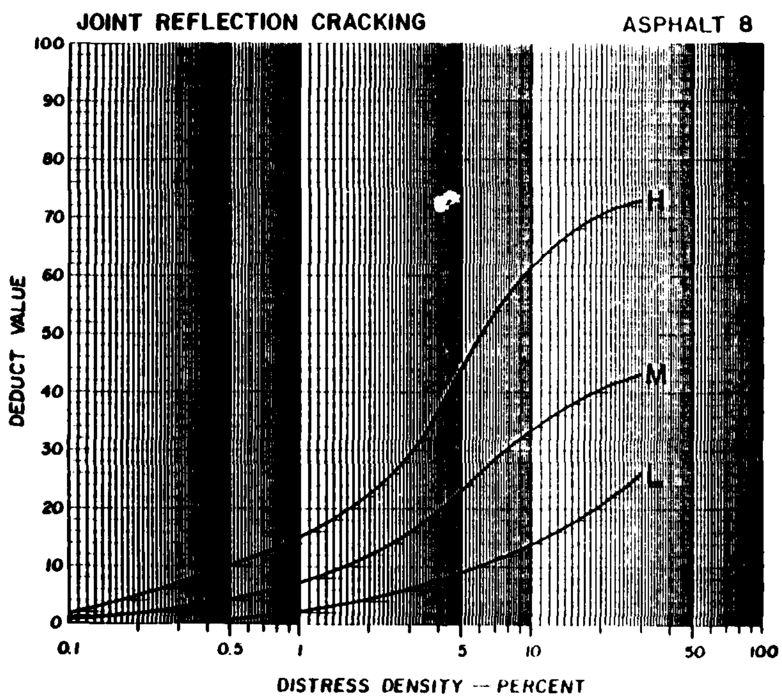

Figure B8. Joint reflection cracking.

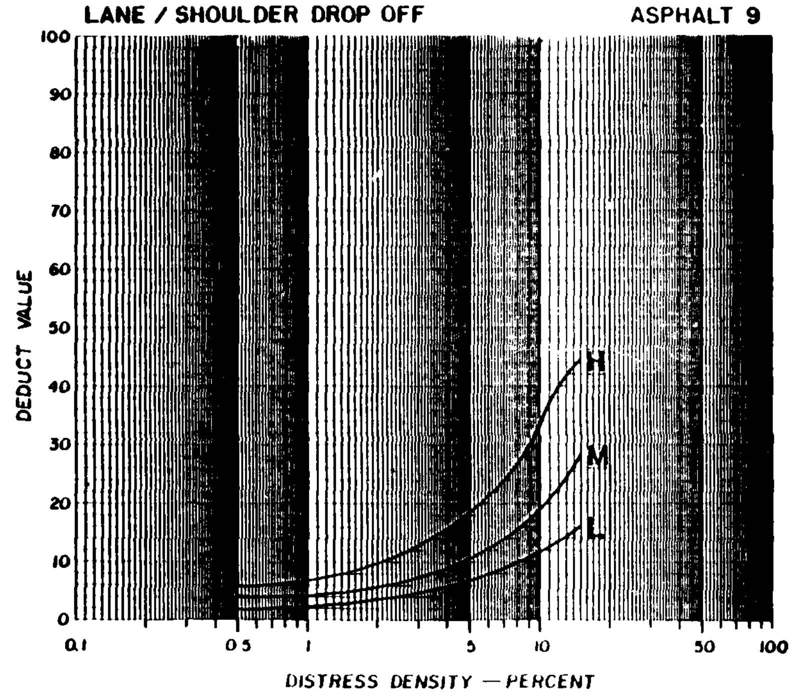

Figure B9. Lane/shoulder drop off.

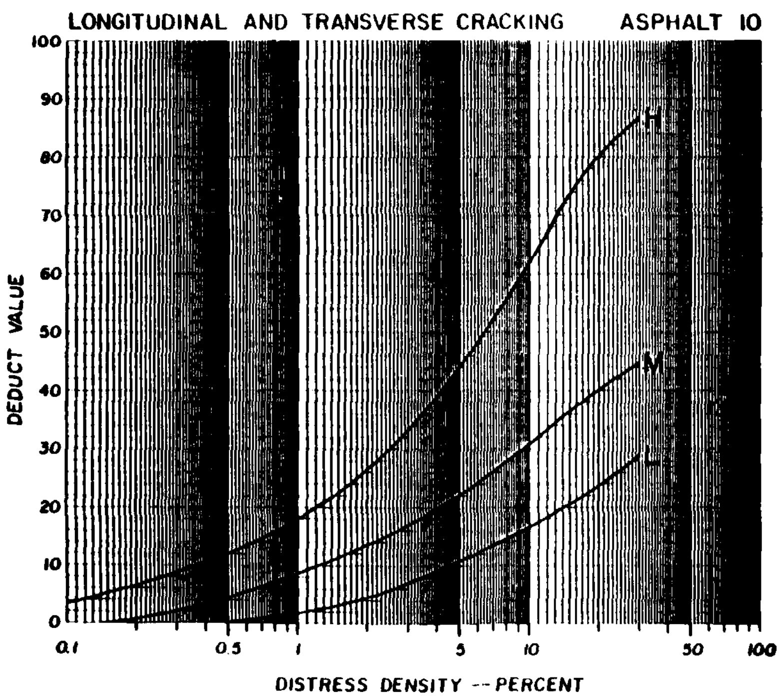

Figure B10. Longitudinal and transverse cracking.

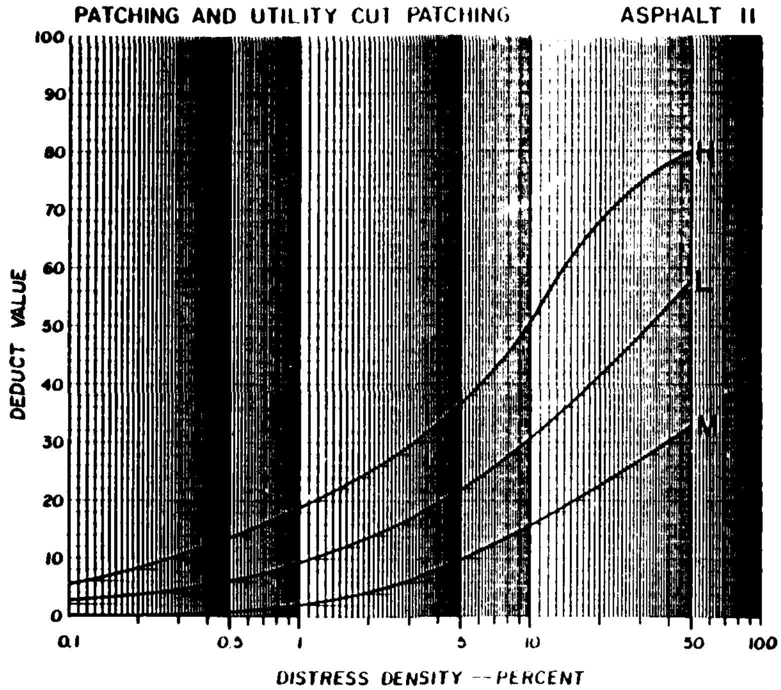

Figure B11. Patching and utility cut patching.

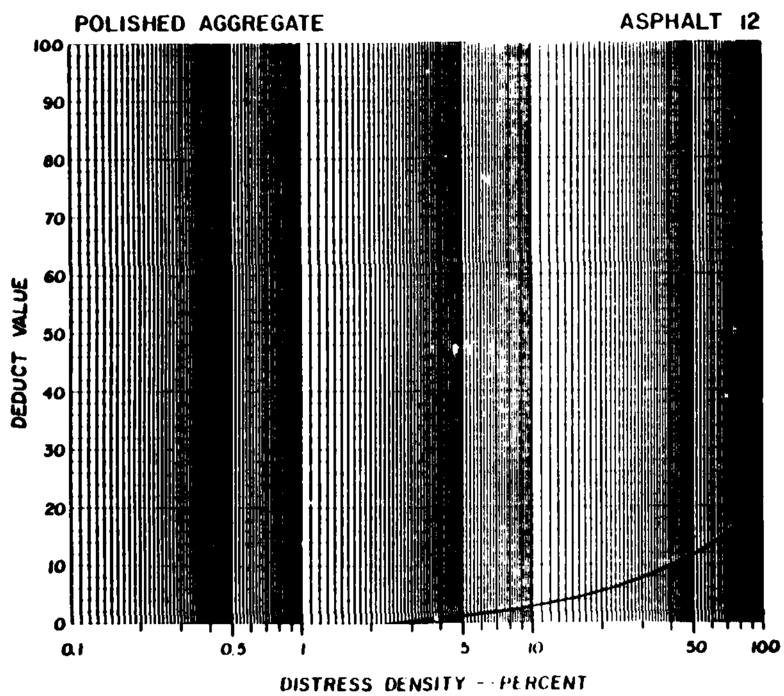

Figure B12. Polished aggregate.

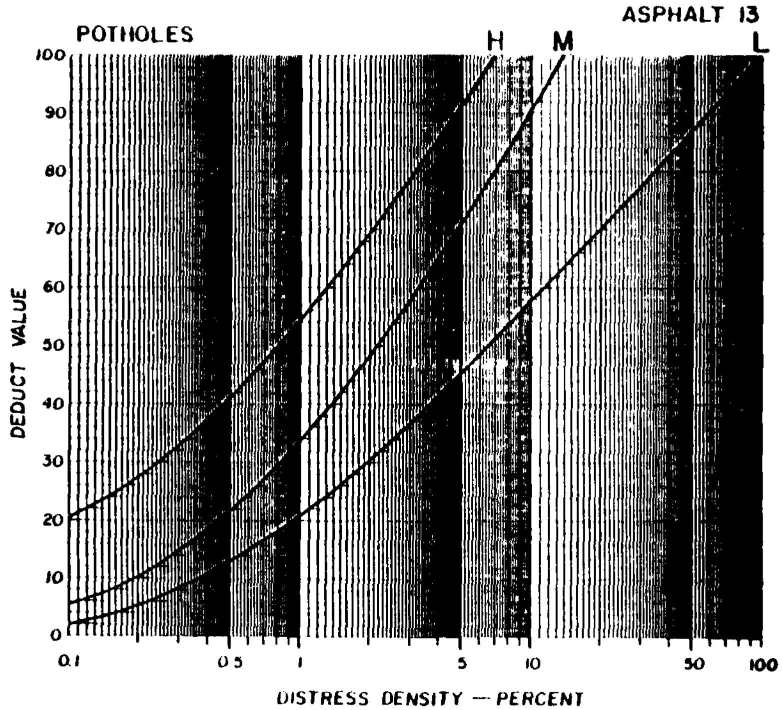

Figure B13. Potholes.

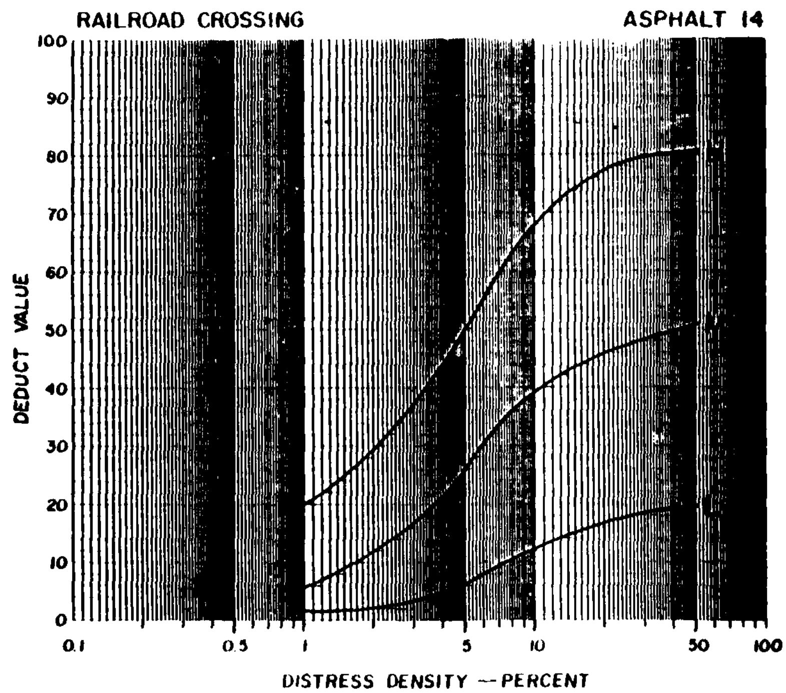

Figure B14. Railroad crossing.

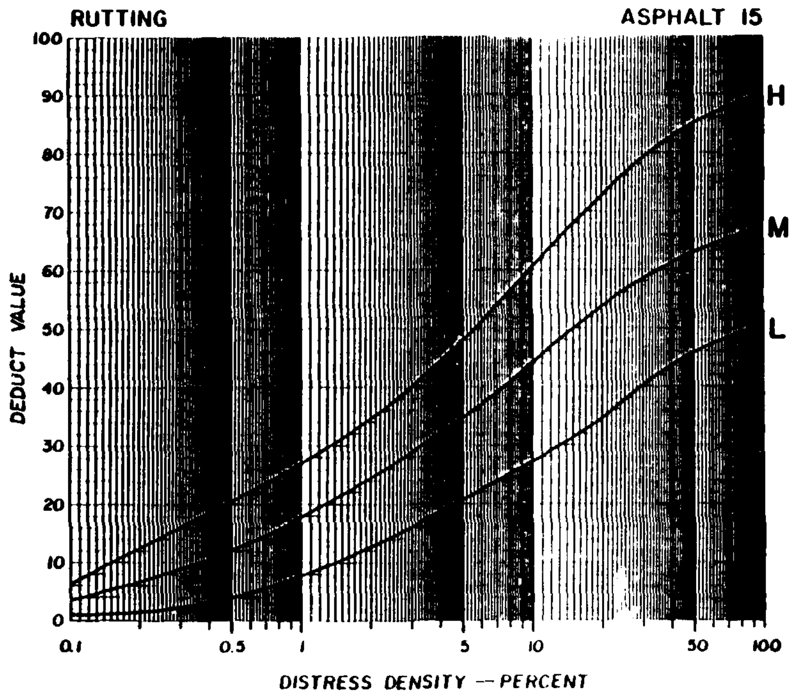

Figure B15. Rutting.

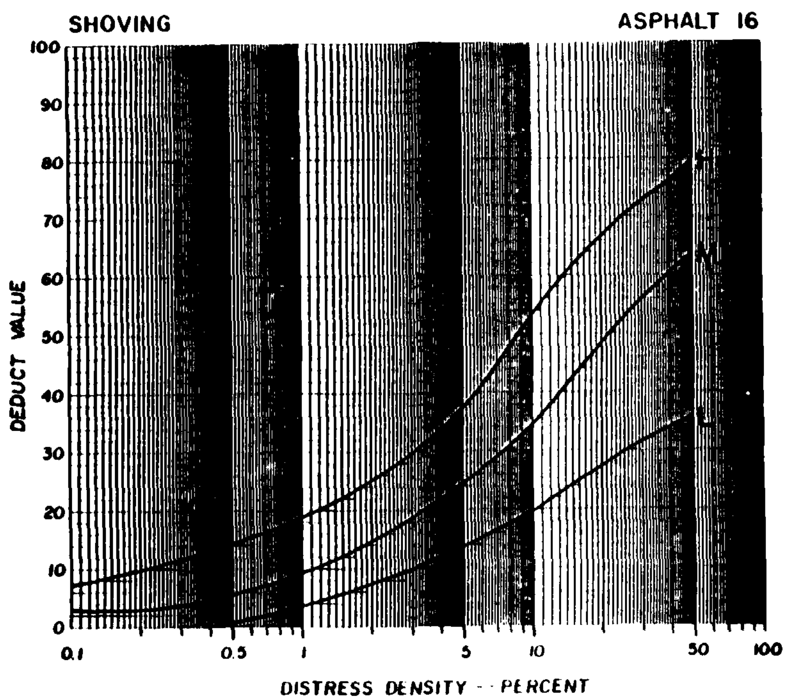

Figure B16. Shoving.

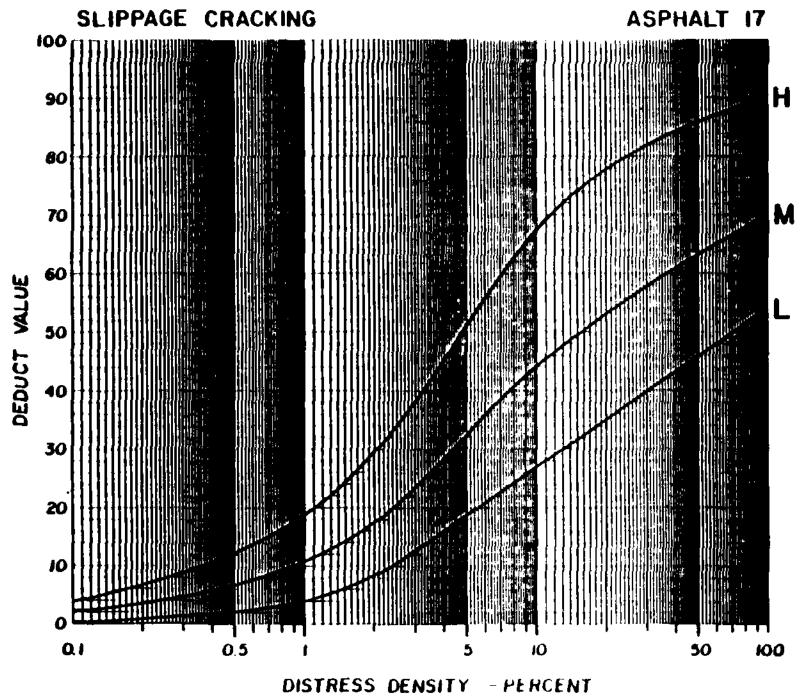

Figure B17. Slippage cracking.

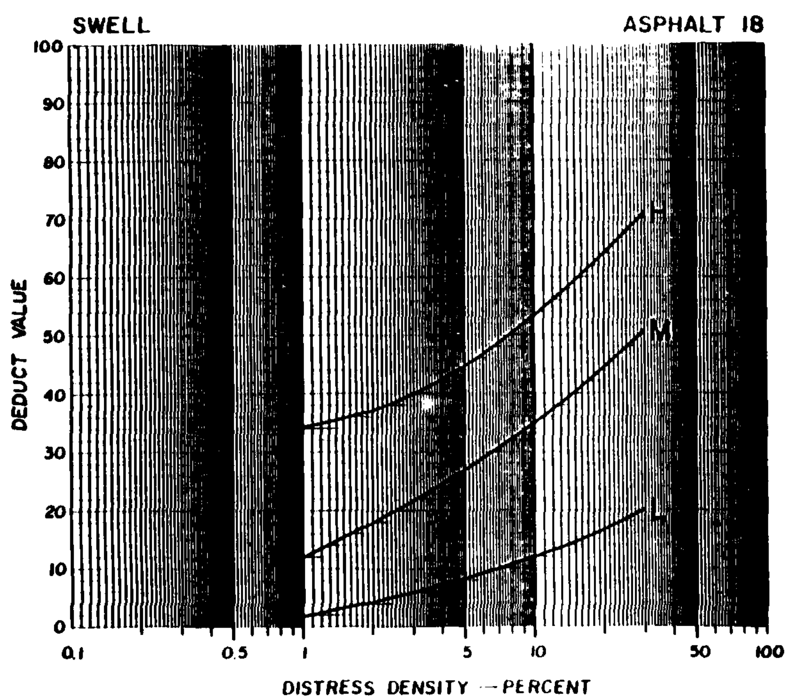

Figure B18. Swell.

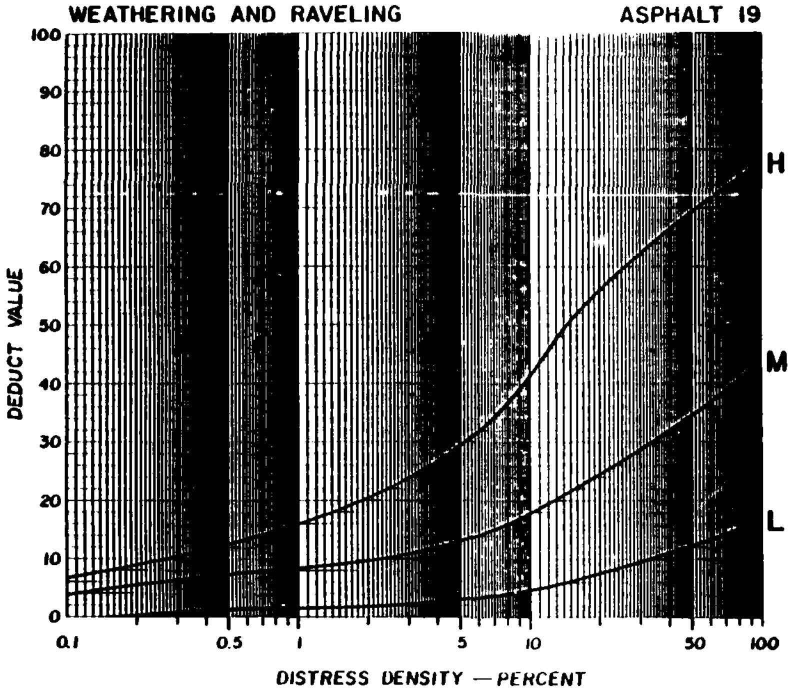

Figure B19. Weathering and raveling.

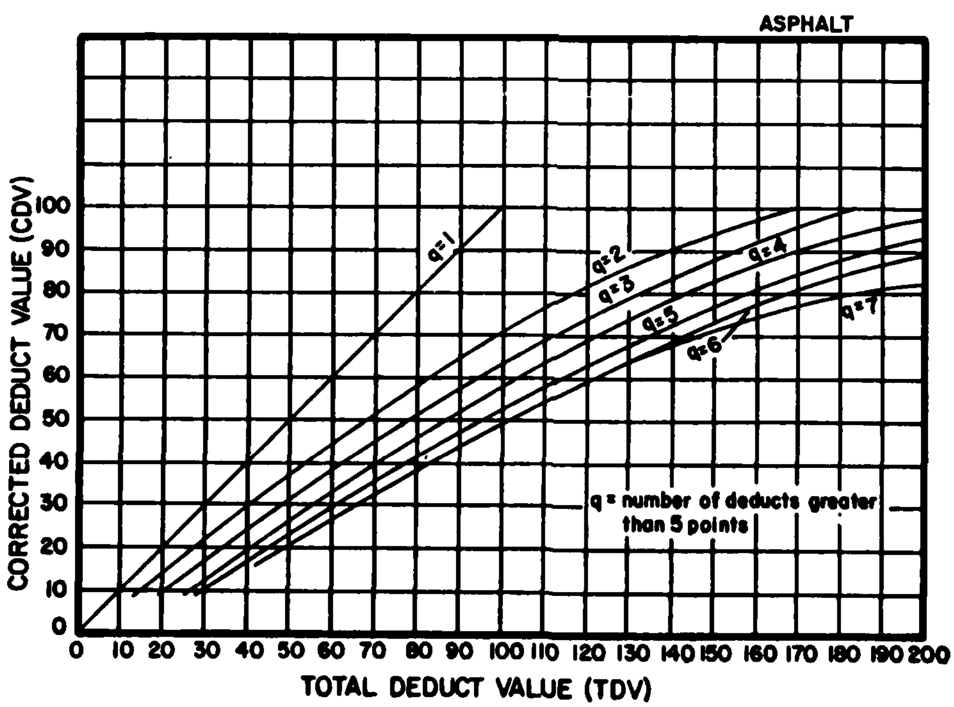

Figure B20. Corrected deduct value curves for asphalt-surfaced pavements.

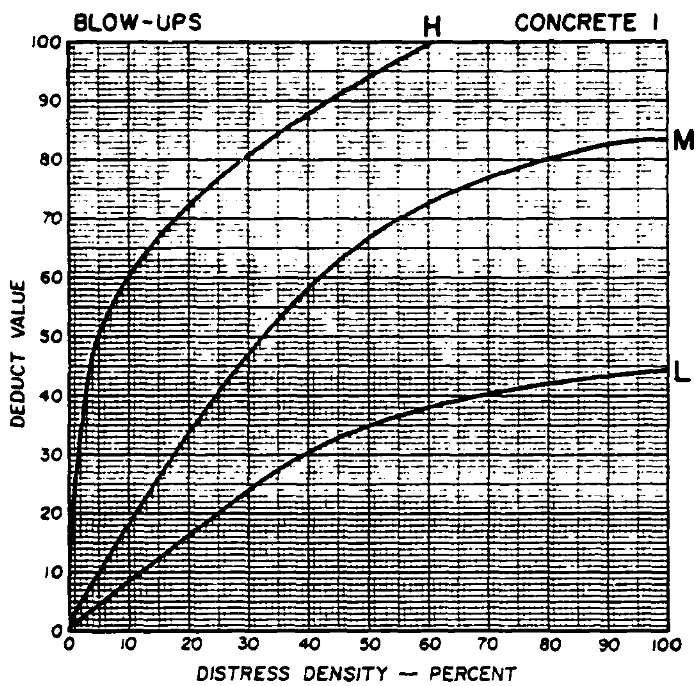

Figure B21. Blow-ups.

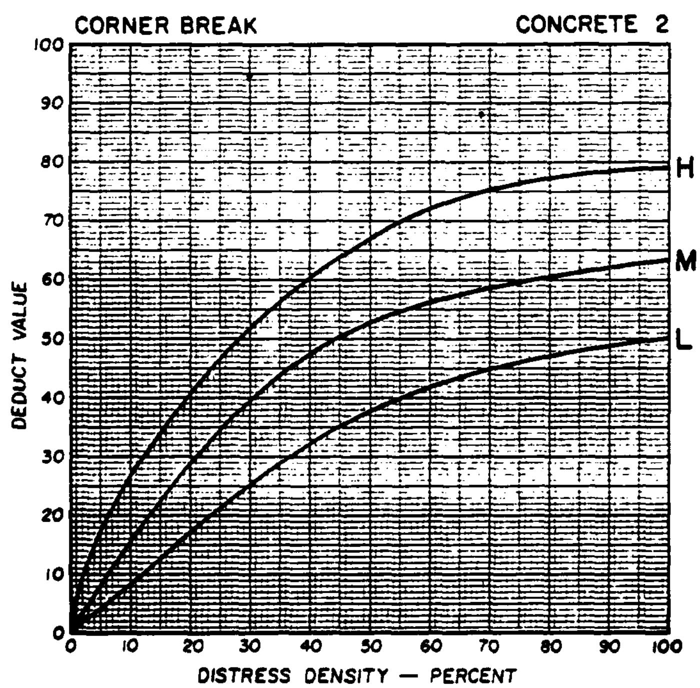

Figure B22. Corner break.

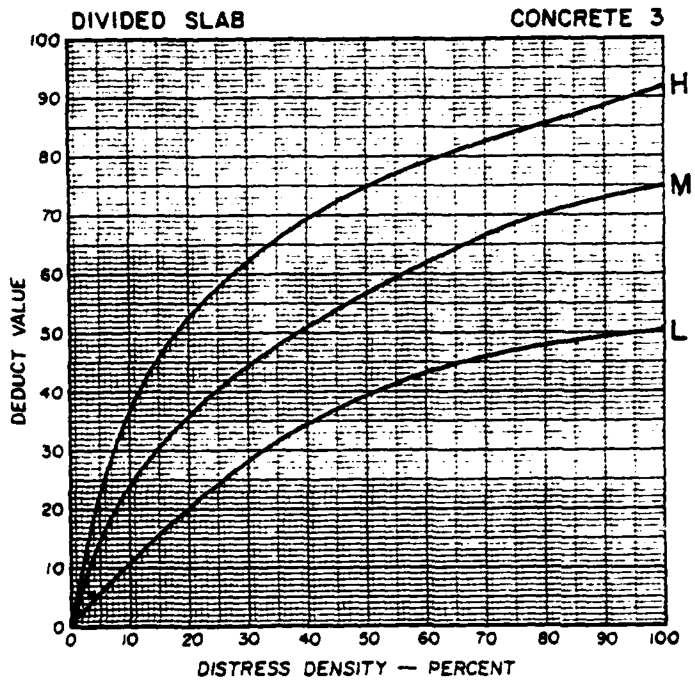

Figure B23. Divided slab.

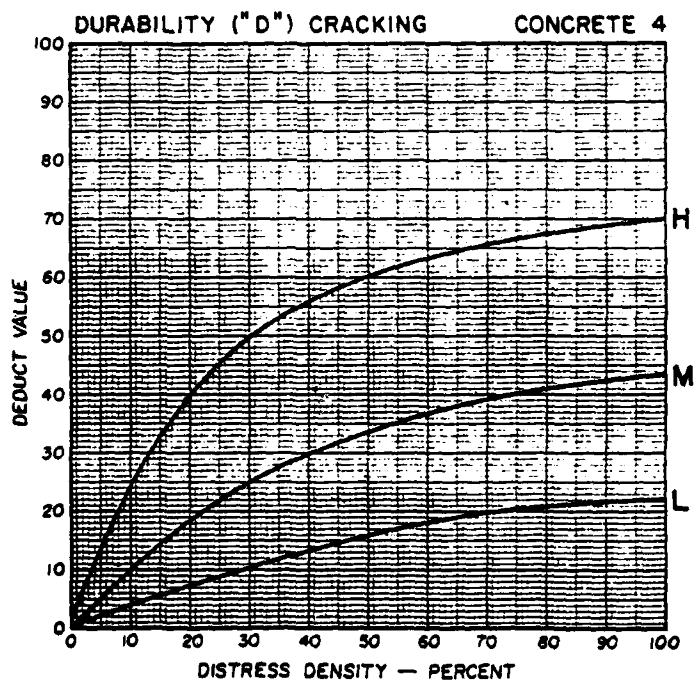

Figure B24. Durability ("D") cracking.

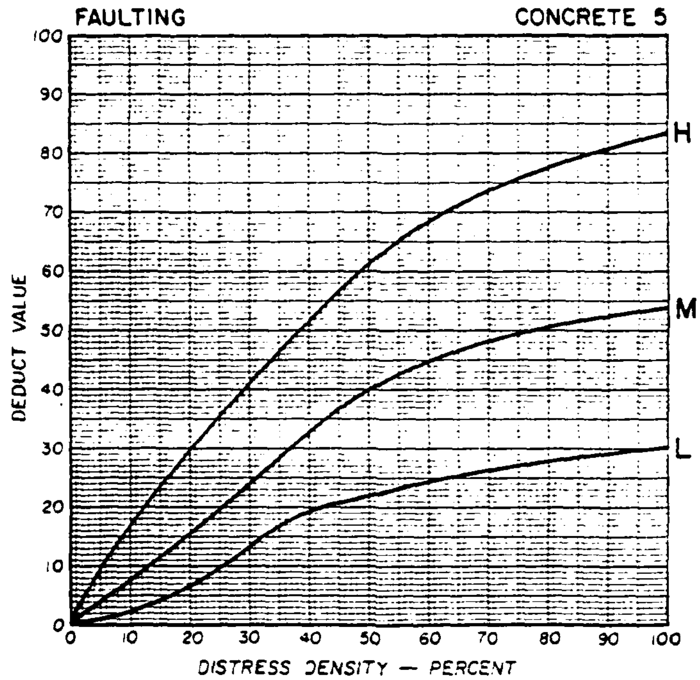

Figure B25. Faulting.

Joint seal damage is not rated by density. The severity of the distress is determined by the sealant's overall condition for a particular sample unit.

The deduct values for the three levels of severity are:

LOW	2 points
MEDIUM	4 points
HIGH	8 points

Figure B26. Joint seal damage.

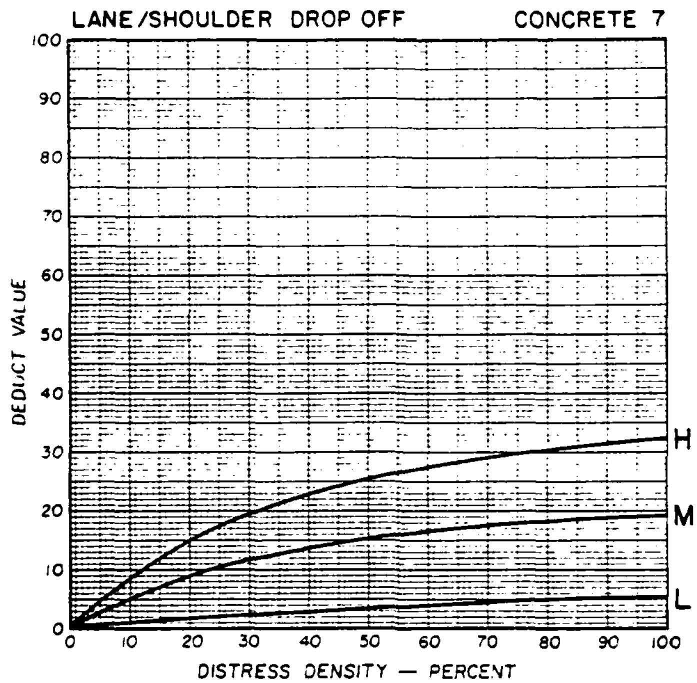

Figure B27. Lane/shoulder drop off.

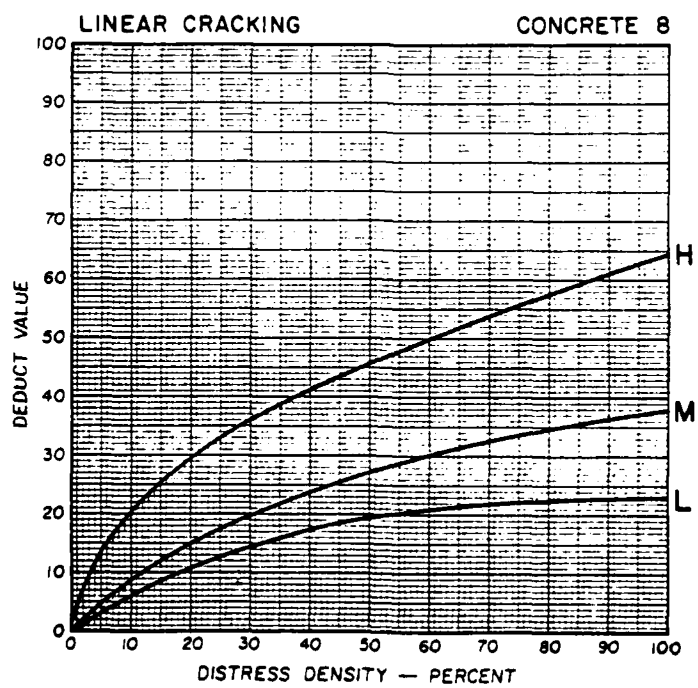

Figure B28. Linear cracking.

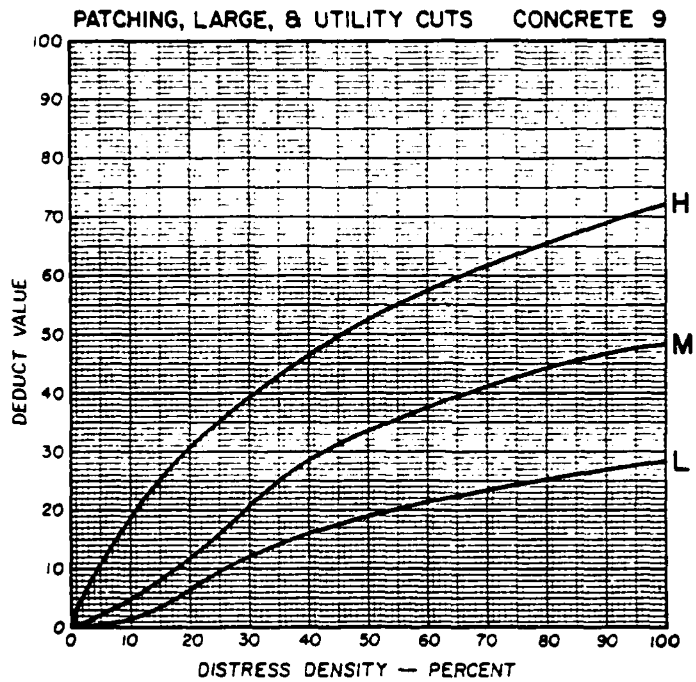

Figure B29. Patching, large, and utility cuts.

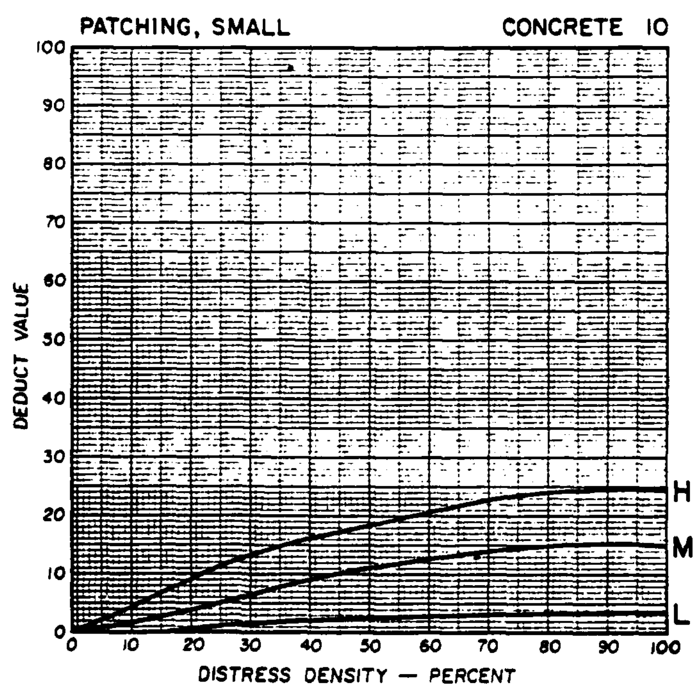

Figure B30. Patching, small.

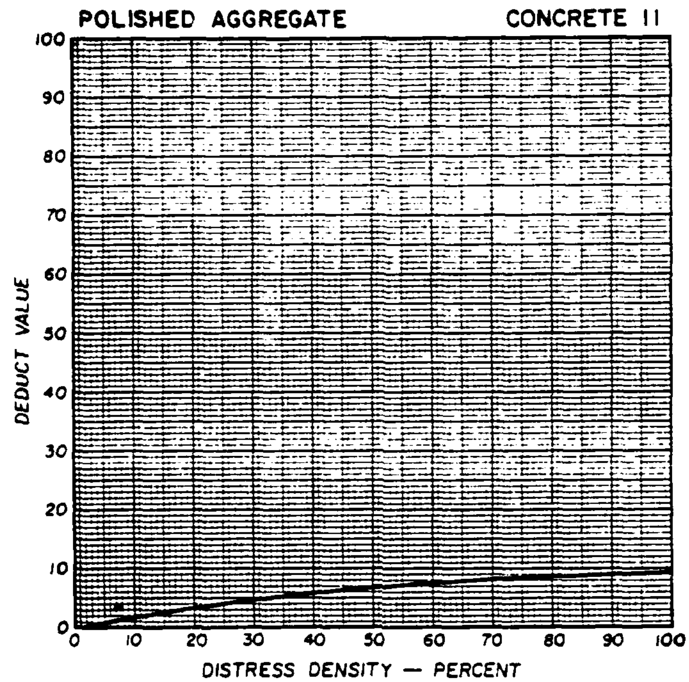

Figure B31. Polished aggregate.

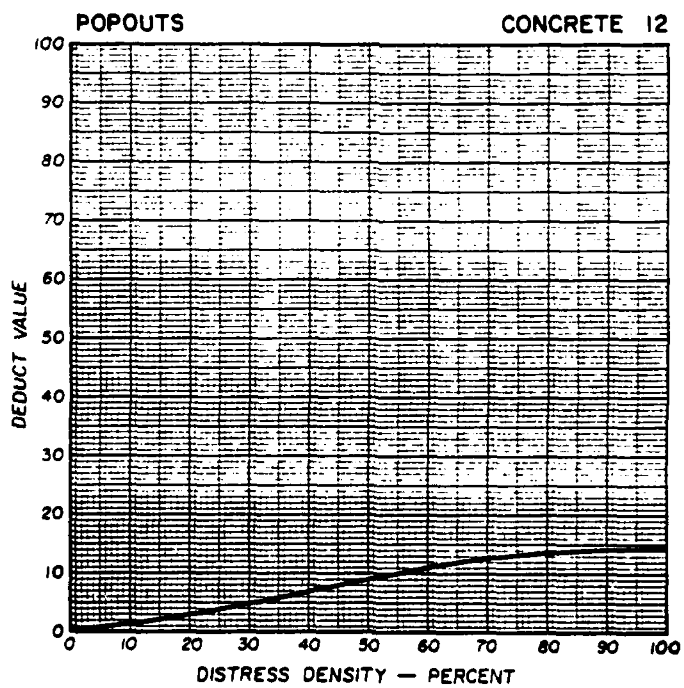

Figure B32. Popouts.

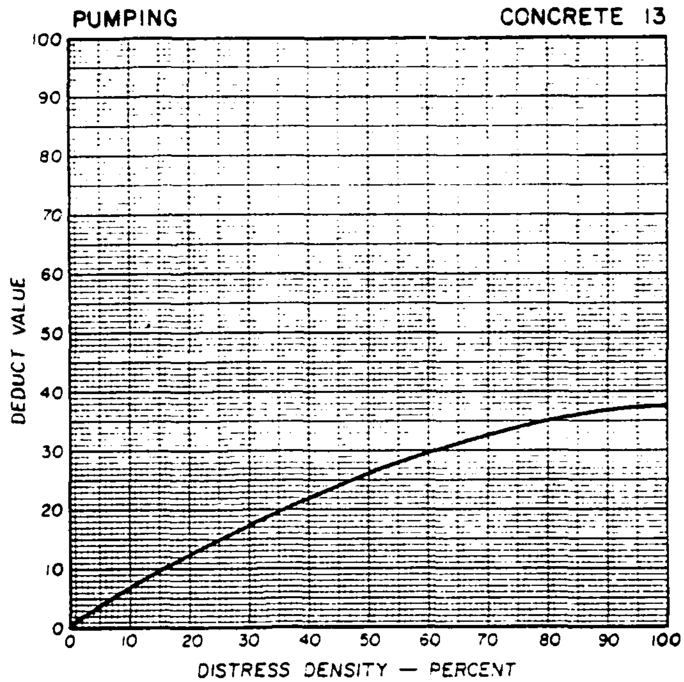

Figure B33. Pumping.

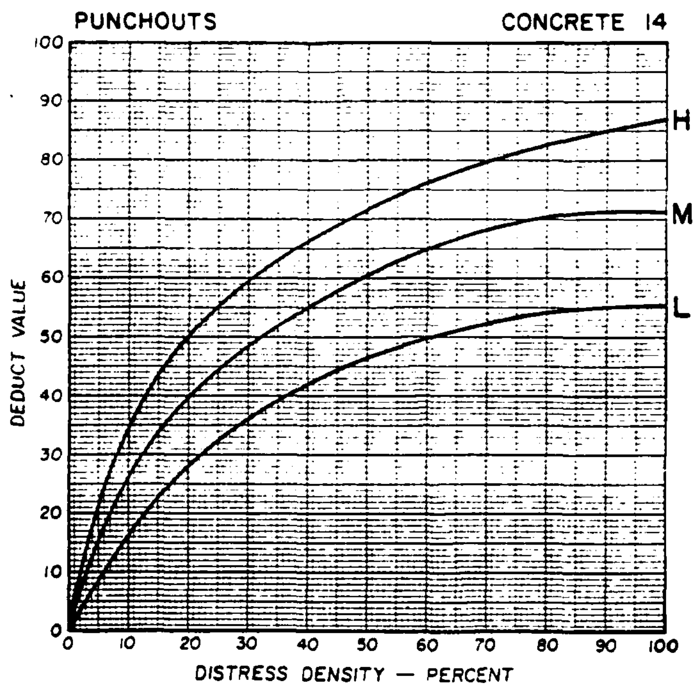

Figure B34. Punchouts.

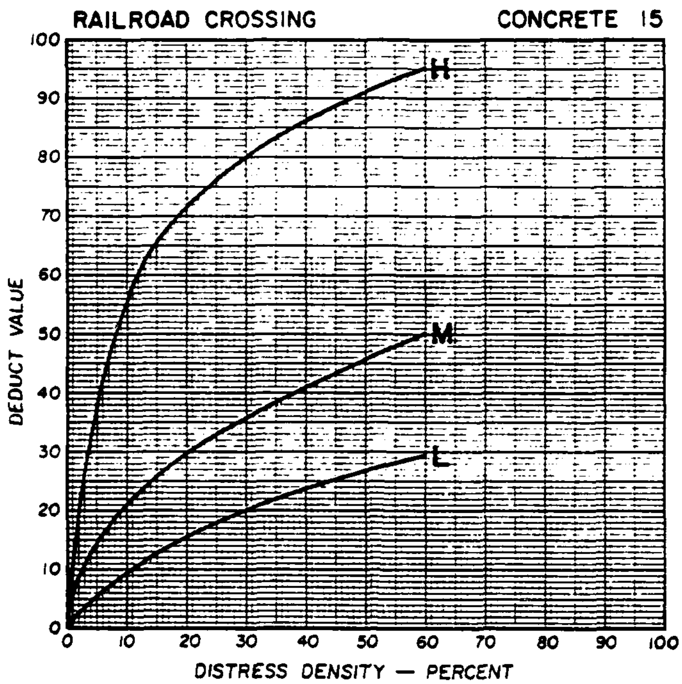

Figure B35. Railroad crossing.

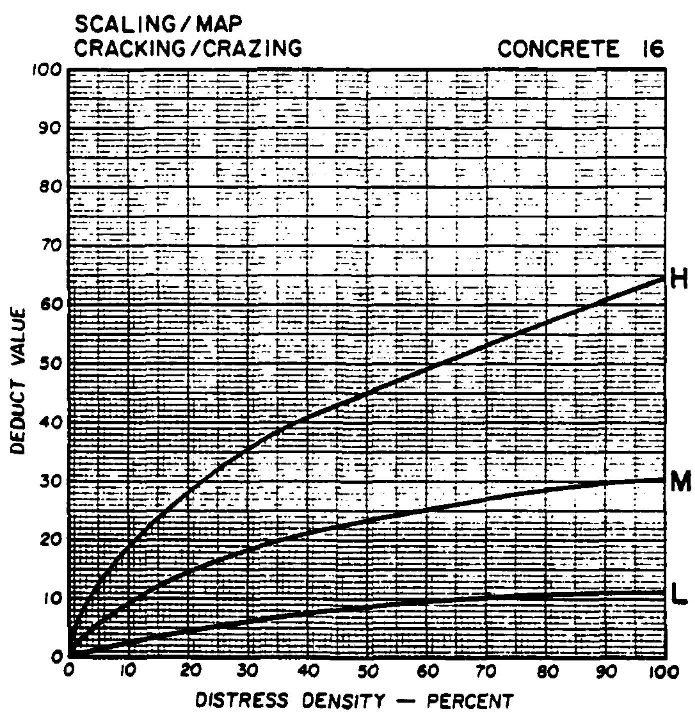

Figure B36. Scaling/map cracking/crazing.

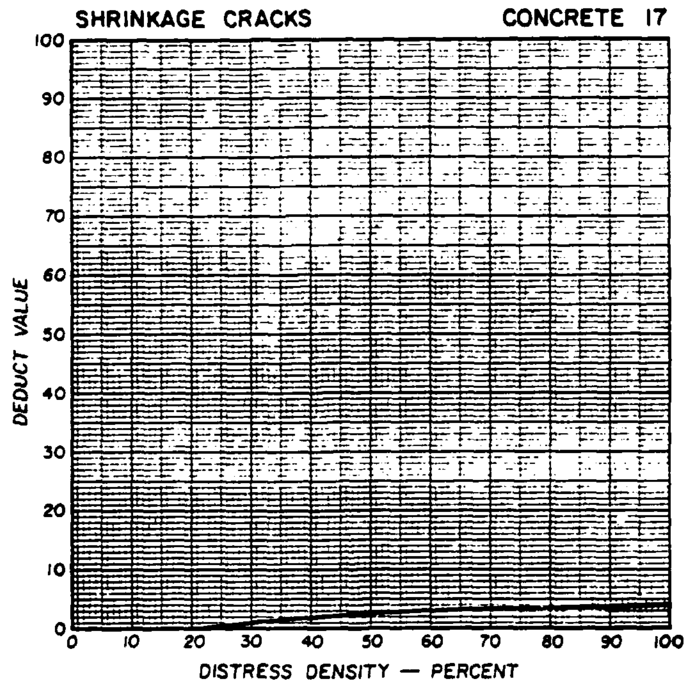

Figure B37. Shrinkage cracks.

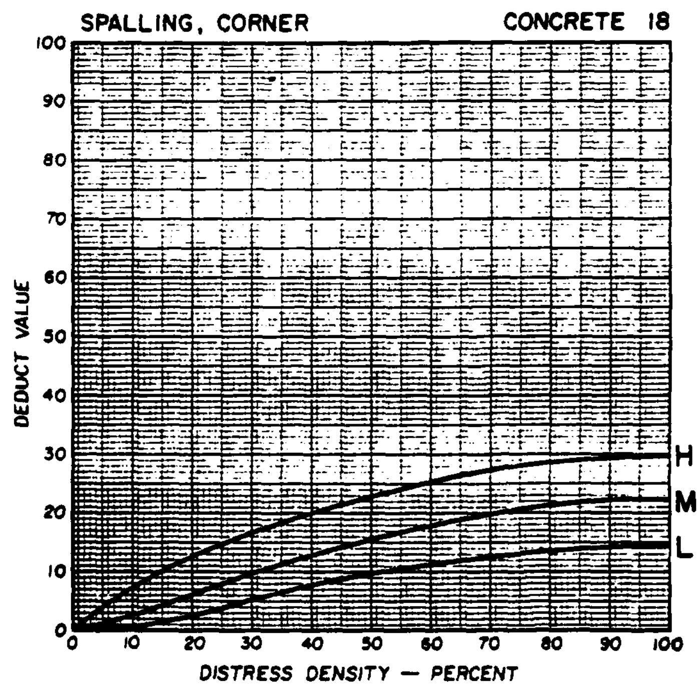

Figure B38. Spalling, corner.

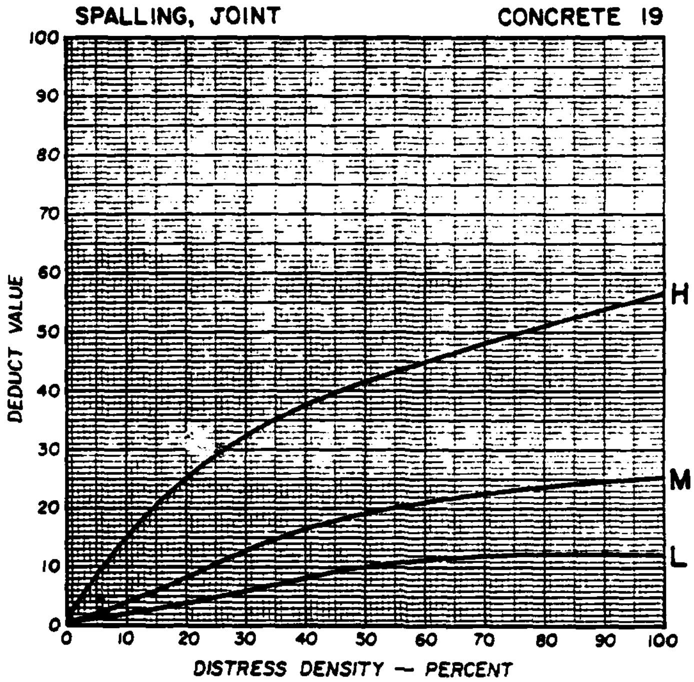

Figure B39. Spalling, joint.

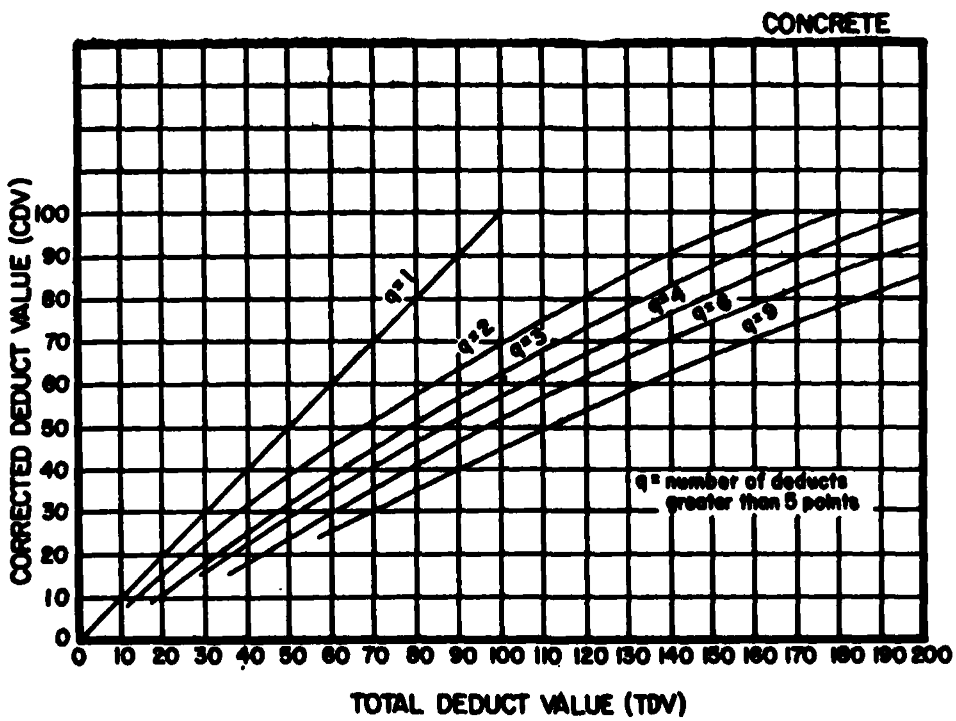

Figure B40. Corrected deduct values for jointed concrete pavement.

APPENDIX C

BLANK SUMMARY AND
RECORD FORMS

CARD 1 - - BRANCH IDENTIFICATION SUMMARY

Sheet 1 of ___

Installation			Date			Up Dates						Total No. of Branches
Code	Name	Location	Mo.	Da.	Yr.	1.			3.			
						2.			4.			
									5.			

Branch Code					Branch Name	Branch Use	Number of Sections	Branch Area Sq. Yd.

Remarks: ___

Sheet ___ of ___

CARD 1 - - BRANCH IDENTIFICATION SUMMARY
CONTINUATION SHEET

Branch Code	Branch Name	Branch Use	Number of Sections	Branch Area Sq Ft.

Remarks: ______________________________

CARD 2 - - SECTION IDENTIFICATION RECORD

Installation Name	Date	Branch Name	Section Area	No. of Sample Units	Section No.
			____ ft.x ____ ft. ____ sq.yd		

Traffic Types And Uses				General Information		
				Curb And Gutter	Sidewalks	Surface Type
O Aircraft O Fixed Wing O Rotary Wing	O Runway O Taxiway O Parking or Pads O Apron O Other	O Vehicular O Real Property O Family Housing	O Primary O Secondary O Tertiary O Parking - Storage O Other	O Left O Right O None	O Left ____ ft O Right ____ ft O None ____	O PCC O AC O Surface Treatment O Other

Sketch:

On sketch, note any subsurface drainage (type, location) and secondary structures, such as manholes, water shut offs, etc

CARD 3 - - SECTION PAVEMENT STRUCTURE RECORD

Installation Name	Date			Branch Name	Section Number

		Material	Material Code			Thickness (in.)	Date Const.	Location (If less than entire section)* From	To
Surface Treatment	Surf Treat (3)								
	Surf Treat (2)								
	Surf Treat (1)								

Overlays	Overlay (3)								
	Overlay (2)								
	Overlay (1)								

		Material	Material Code			Thickness (in.)	Date Const.	Comments
Initial Construction	Surface							
	Leveling							
	Base							
	Subbase							
	Select							
	Compacted Subgrade							
	Natural Subgrade							

*New Section of Branch Must Then be Identified

CARD 4 - - SECTION MATERIALS PROPERTIES RECORD

Installation Name	Date			Branch Name	Section Number

Pavement Layer	Material Properties	Value/Unit	Comments

CARD 5 - - SECTION TRAFFIC RECORD

Installation Name	Date			Branch Name	Section Number

Roads or Streets																								
Date of Survey																								
Traffic Type	a	b	c	d	e	f	a	b	c	d	e	f	a	b	c	d	e	f	a	b	c	d	e	f
Volume Index																								

Parking Lots - Airfields - Other	
Date of Survey	Description

CARD 6 - - SECTION CONDITION RECORD

Installation Name	Branch Name	Date			Section Number

Average PCI ____ Condition Rating ____

Ride Quality G__ F__ P__ Safety G__ F__ P__ Drainage G__ F__ P__

Total No. of Sample Units ____ No. of Random Units Surveyed ____

No. of Additional Units Surveyed ____

PCI Range ____ Minimum of Units to be Surveyed ____

Pavement Type
○AC ○PCC

Section Area
25 ft. x 500 ft.
1388 sq. yd.

Section Distress Data
○ Extrapolated Quanities ○ Actual Quantities

Distress Type	Severity Level	Quantity	Section Density	Deduct Value	Comments
			Total		

Percent Deducts Structural Related ____ Enviromental ____ Other ____

CARD 7 - - BRANCH MAINTENANCE & REPAIR REQUIREMENTS

Sheet ______ of ______

Installation Name	Date	Branch Name	Total No of Sections

Work Class : M - Maintenance R = Repair C New Construction Location : R Roadway PL Parking Lot A : Airfield O Other

Section No.	Work Description	Work Class	Loc	Thickness, inches	Quantity/Unit	Est Cost	Priority	Date Completed, M/Y

Remarks ______

CARD 8 - - SECTION MAINTENANCE AND REPAIR RECORD

Sheet ..... of .....

Installation Name	Date			Branch Name	Section Number
	Mo	Da	Yr		

Work Performed					
Date of M&R	Description of Work	Location	Thickness	Quantity/Unit	Cost

Remarks ____________________

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227 p. (Technical report ; M-294)

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Figures B11 and B13 on pp. 193 and 194, respectively, contain errors. Please replace these pages with the attached copy.

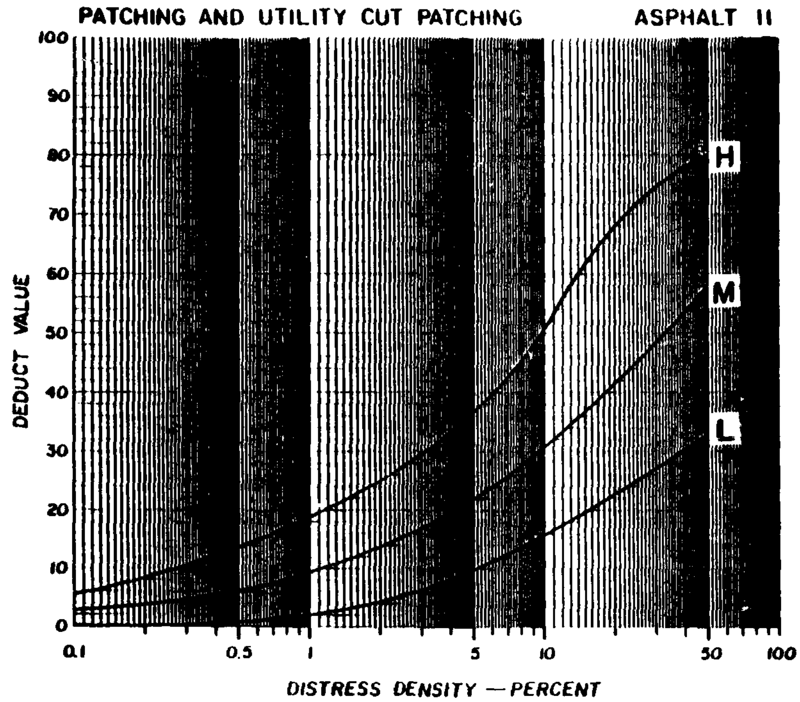

Figure B11. Patching and utility cut patching.

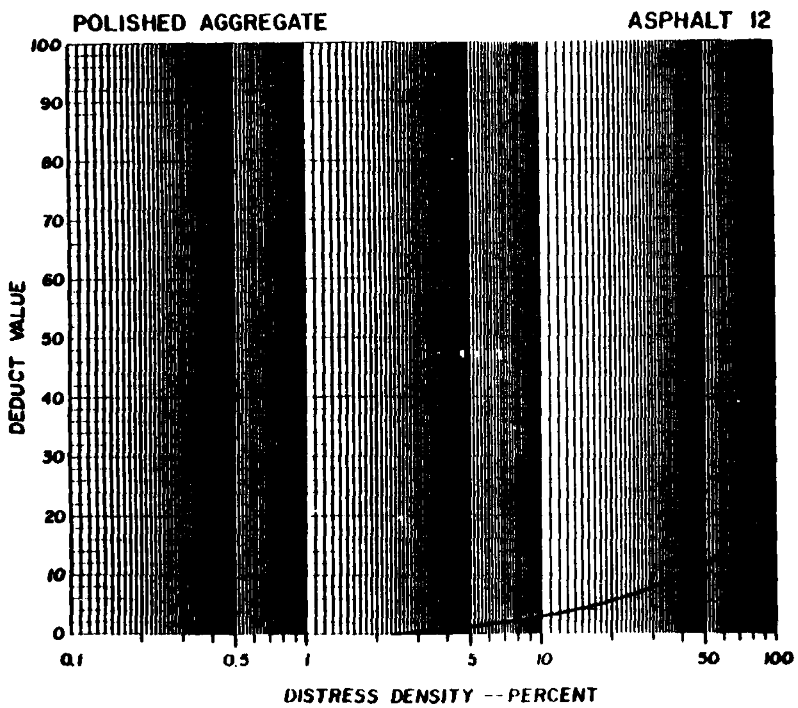

Figure B12. Polished aggregate.

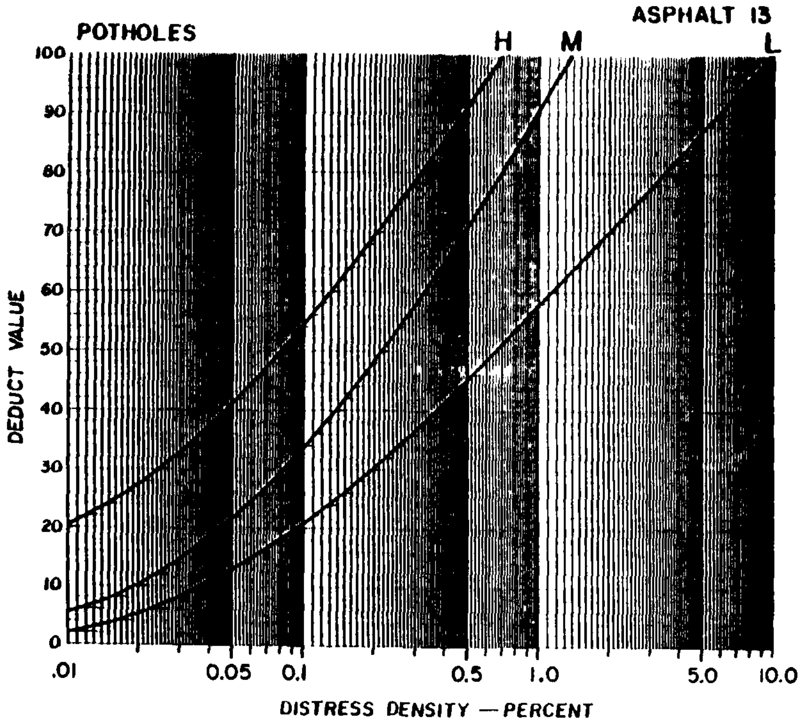

Figure B13. Potholes.

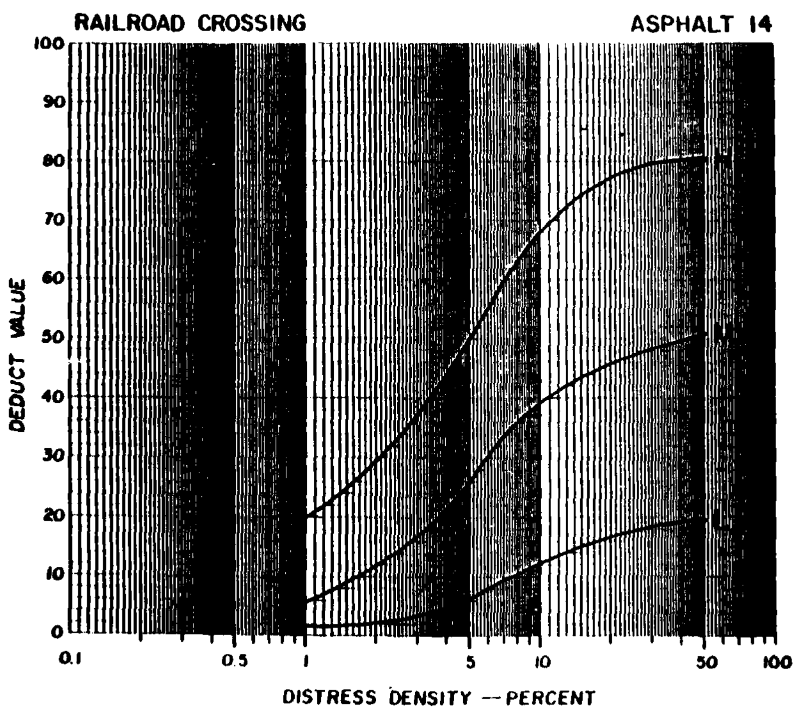

Figure B14. Railroad crossing.